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Page 19, line 1, *read* 38% *for* 38.

Page 107, paragraph 1, lines 1, 3, and 4, *change* macrocarpa *to* macrospora.

Page 111, title, line 4, *read December for January.*

Page 142, line 5, *change* about 80 per cent *to* above 70 per cent.

Pages 369, 371, 373, 375, 377, 379, 381, 383, 387, 389, running heads, *read* stripe *for* barley.

Page 395, paragraph 2, line 4, *change* $\sigma^2_{A-B} = \sigma^2_A + \sigma^2$ *to* $\sigma^2_{A-B} = \sigma^2_A + \sigma^2_B$.

Page 408, table title, *change* of the uredospores *to* to the uredospores.

Page 411, table 10, *change* 5 c.c. N/10 in 100 c.c. *to* 5 c.c. N/10 NaOH in 100 c.c.

Page 414, paragraph 5, line 2, *read* pentathionates *for* penathionates.

Page 415, reference 6, *read* e *for* ed.

Page 416, reference 27, *read* Polythionaten *for* Polythionen.

Page 431, footnote, line 2, *after* Pathology *insert* and Agricultural Chemistry.

Page 480, paragraph 1, line 7, *read Heliothrips for Haliothrips;* line 8, *read vaporariorum* for *vaporarium.*

Pages 506 and 507, *interchange* entire figure legends.

Page 520, paragraph 5, line 4, *change* high (30° C.) *to* at a high temperature (30° C.).

Page 663, paragraph 2, line 9, *after* Zehner *add* and Humphrey.

Page 668, reference 9, *after* Zehner, M. G., *add* and Harry B. Humphrey.

Page 679, line 7, *read* Bensaude *for* Bensuade.

Page 680, reference 3, *read* racines *for* racine.

Page 689, line 1, *change* A. Lange Norbert *to* Norbert A. Lange.

Page 703, item 4 under *Philippine organism, change* three *to* two.

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THE GENUS PHYTOMONAS

WALTER H. BURKHOLDER

Unlike the fungous plant pathogenes, found in a great many families and genera scattered throughout the three main groups of the fungi, the bacteria which cause diseases in plants are restricted to a rather limited group in the Eubacteriales. The large number of known species of these bacterial pathogenes is continuously increasing, but the genera to which they belong in the various systems of classification are few. Briefly described, the bacterial plant pathogenes are nonspore-forming aërobic, motile or nonmotile rods. Other restrictions could be placed on the group that would limit it still further, but the description would become highly involved and not very helpful. The above simple description suffices for our purposes, and perhaps some objections to it could be brought forth from the literature on the subject. These objections, however, are very few and at times open to some doubt. *Bacillus mesentericus* as a plant pathogene is an outstanding example, but even this spore-forming organism causes only a tuber rot and not a disease of the growing plant. The brief description of the plant pathogenes as given above is practically correct and covers those forms dealt with in this article.

With such a small group of organisms to consider, one naturally would be of the opinion that little difficulty would be experienced with its taxonomy. In this case, however, the reverse is true. A confusion exists here that is not equalled in any one group of the fungi engaging the interest of plant pathologists. This confusion, too, is not of recent occurrence, but has existed for some time and is now of almost everyday unconcern. Everyone recognizes it, but no one does anything about it. It is at present, to a considerable extent, treated with levity.

This confusion in the nomenclature of the bacterial plant pathogenes is due to the general use by the plant pathologists of various systems of classification. There are several of these systems each of which is recognized and the investigator in bacterial diseases of plants merely expresses a preference for one of them. An example of this may be cited. A new bacterial pathogene is described and given a binomial name, but a footnote frequently will be found stating the system of classification followed and one or two

other generic names which could be used if other classification were employed. Here a preference is shown for one of the systems in use, but the author's allegiance is more than likely to shift in his next article. Also, some authors have refused to make a decision and have used generic names from various classifications. Since several of these generic names occur interchangeably in the various systems, further confusion has arisen and plant pathogenes are recognized now only by their specific name.

The systems of classification in use at the present time by the plant pathologists are those of Migula, Lehmann and Neumann, Erwin F. Smith, and Bergey. The order of the systems given above is more or less chronological. The confusion, or the general use of all four classifications by the plant pathologist, has not come about through differences in basic principles. These principles are practically the same for three of these systems used, and for the fourth, Lehmann and Neumann's, no classification or divisions and subdivisions exist for the plant pathogenes. It appears inexcusable that we should have arrived at such a state of chaos. The reason for having done so can be comprehended only by examining the history of these systems and their adoption by the plant pathologist.

In examining these systems of classification and the extent of their use, one is forced to separate the plant pathologist from the bacteriologist. This is a rather lamentable fact, but nevertheless true. The plant pathologist has drifted away from the science of bacteriology for many years until now there is little contact between the two groups. On the other hand, we have been closely associated with the mycologist with advantages on both sides. The disadvantages in our separation from the bacteriologist are apparent. This separation of the two groups is emphasized here from the fact that each has regarded differently the systems of classification proposed for bacteria.

The true bacteriologist has not been so hampered with systems as has the plant pathologist; in fact, he has, as a rule, paid little attention to them. In the last two decades of the nineteenth century and the beginning of the twentieth, when the spirit of the time was that of classifying and experimenting with classification, Migula's and Lehmann and Neumann's classifications were followed by the bacteriologist. Later, certain features of each of these systems were employed. For instance, the Pseudomonas group (Migula), that is, the rod forms having polar flagella, was recognized, as was also the Bacillus group (Lehmann and Neumann), the forms producing spores. Further recognization of other groups arose and, in the United States, the present drift in nomenclature of the bacteria has, in general, crystallized itself into the Bergey classification. This no doubt will be modified, since complaints are arising on all sides concerning certain of the

genera. The system does show, however, the direction in which the bacteriologists are going in this field.

The American plant pathologists, on the other hand, at first accepted Migula's system, possibly because Erwin F. Smith did. Chester's volume on Determinative Bacteriology also helped to establish this system in America. Lehmann and Neumann's system was and is still more or less unknown to the American plant pathologists. The European plant pathologists, however, especially those on the Continent, follow Lehmann and Neumann, so one is forced to recognize this system in the literature. In 1906, Erwin F. Smith brought forth his classification and, although it was never considered by the bacteriologist, it was immediately adopted by the plant pathologist. There were reasons for this. The plant pathologists were introduced to bacteriology by Erwin F. Smith, and his fight to establish the fact that bacteria can cause diseases in plants is one of the high points in this field. E. F. Smith was preëminent in plant pathology and it was but natural that they should follow his lead in nomenclature. Furthermore, the plant pathologists were all schooled in taxonomic mycology, a subject which at that time was greatly concerned with priority, and Smith's classification was based on priority. No new concepts were expressed. The three systems with the same generic names applied to different groups were now in continual use, and confusion arose. To get away from this state of affairs, a few adopted Bergey's system when it arrived. Entirely new generic names were applied here.

In showing a preference for one of the systems of classification it would be reasonable to expect an investigator to examine the basis for each classification. Perhaps this is being done, but a discussion of this phase of the subject, as far as I know, has not appeared in literature. And, since the basis for classification is of primary importance, it seems pertinent to review it here. Migula used the presence and absence and mode of attachment of flagella as generic characters in his classification. The genus Bacterium is composed of nonmotile forms; Bacillus, of forms motile by peritrichous flagella; and the genus Pseudomonas is composed of rods which are motile by means of polar flagella. When Erwin F. Smith presented his classification of bacteria in 1906, he still considered the presence and absence and the position of flagella as sound generic characters, but digressed from Migula in the following manner. He held that the generic name Bacterium had priority over Pseudomonas, since Cohn (1872) had first used it for the rod forms having polar flagella. This consequently left the nonmotile forms without a name; so Aplanobacter was coined for this genus. Smith was not the only one to point out the priority of the name Bacterium over Pseudomonas. Vuillemin (1913) independently reached the same conclusion.

Since at that time (1906) a starting point for nomenclature for bacteria had not been agreed upon, Smith's arguments are logical if one accepts his basis for generic characters.

Nevertheless, due to the fact that the term Pseudomonas was probably so well established, bacteriologists failed to regard these disclosures with interest. The situation also was further complicated by the increasingly large group of workers in bacteriology who held that the presence and absence of spores were of generic significance and that flagella were of minor importance. Consequently, for them, Smith's or Vuillemin's conclusions would have no bearing on change of generic names. It was upon this basis that Lehmann and Neumann had presented their system of classification, namely, the presence or absence of spores. In the genus Bacillus they placed all rod forms producing spores. The genus Bacterium was composed of those which did not produce spores. It may be seen readily that all plant pathogenes would fall in this last genus.

A most radical digression from the systems of classification just described occurs in that of Bergey, in that all the plant pathogenes are placed in a separate tribe, Erwinieae. The first step in this direction had appeared in the Final Report of the Committee of the Society of American Bacteriologists on Characterization and Classification of Bacterial Types, when the tribe Erwinieae was proposed for the plant pathogenes in the family Bacteriaceae. Bergey, however, went further and made a new genus, Phytomonas, composed of motile plant pathogenes from the genus Pseudomonas of the Committee's report, together with the nonmotile plant pathogenes. The new genus, Phytomonas, was then placed in the tribe Erwinieae, next to the genus Erwinia. This tribe is based entirely upon the ability of its members to cause disease in plants, and all other characters of the bacteria are disregarded. The reason for the separation of the plant pathogenes was not discussed and it seems evident that the close relationship of the genus Erwinia to the coli group, and of certain members of the genus Phytomonas to the fluorescent group was overlooked or not known. In the general classification of bacteria, Bergey does not always use the character of pathogenicity to separate groups. He does follow this system in the families Bacteriaceae and Coccaceae, but not in the families Bacilliaceae and Spirillaceae. In the Actinomycetes he has allowed certain of the forms pathogenic to plants to associate with animal pathogenes and saprophytes. He is not entirely consistent.

The use of pathogenicity as a character of such importance as to separate tribes and genera should be considered closely before adoption. It has never been employed in the main groups of fungi. The close relationship of many members of the genus Erwinia to *Escherichia coli* Escher-

ich has been mentioned. *Phytomonas marginale* Brown can scarcely be distinguished from *Pseudomonas aeruginosa* Schröter. Nonpathogenic forms of *Phytomonas tumefaciens* Smith and Townsend are evidently numerous in the soil, and, so far as Bergey's classification goes are at present, homeless. Furthermore, pathogenicity is in many bacteria a very delicate character and may be lost quickly when the organism is grown in pure culture. The same thing probably occurs in nature under adverse conditions.

A system of classification for bacteria seeking to be a natural system should be workable as well, and primary characteristics should be considered first. Many plant pathogenes are not always found associated with their host plant. In isolating an organism under such circumstances the character of pathogenicity would have to be disregarded from the very nature of the case. Only a plant pathologist searching for a definite species would think of making inoculation tests. One would not know what plant out of hundreds to use. The test would be unthought of until many of the characteristics were determined and the organism appeared to be a certain pathogene. By that time, alas, its pathogenicity might have been lost. Rahn (1929) in his article, "Contributions to the classification of Bacteria," has emphasized this point under the title of "Practical Impossibilities in Taxonomy."

In considering the subdivisions in the tribe Erwinieae of Bergey, one finds that his separation of the two genera is based primarily on the presence and absence and position of flagella. He only digresses from Migula and from Smith in that he places the nonmotile pathogenes in the same genus with the forms possessing polar flagella. This move has proved a little disconcerting to the plant pathologist since it has been felt by some that the nonmotile forms are a distinct group. The separation of the genus Erwinia on the character of peritrichous flagella is orthodox and probably justifiable; at least, there is no indication to the contrary. The genus is a well-recognized group and each species possesses this character.

ANALYSIS OF THE GENUS PHYTOMONAS

Having pointed out the defects of Bergey's classification, I still follow it because of its clarity and efficiency. One is not required to use a footnote. Furthermore, plant pathology is too interdependent on the other sciences to become isolated, especially in matters of taxonomy. We must look to the systematist in bacteriology just as we do in mycology or phanerogamic botany, although in this case the bacteriologists have treated us rather shabbily. We can, however, call attention to defects in systems of classification and, furthermore, point out methods of construction for bettering these systems. The remainder of this article is such an attempt.

It is felt that the basis for classification of the bacterial plant pathogenes was established when the number of the pathogenes was small and our information concerning them was meager. The number of known species is now many, considerably over a hundred, and it is time to take stock of what knowledge we have of these forms. In this article I do not intend to examine all the bacterial pathogenes, but to confine myself only to one genus of the Bergey classification. This genus, Phytomonas, is chosen for the following reasons: First, it contains by far the larger number of species of the two genera of the tribe Erwinieae and appears to be a rather heterogeneous mixture. The question arises whether or not it can be considered as one genus. Also, the genus combines the nonmotile forms with the motile forms having polar flagella, and it should be determined whether or not this is justifiable. And third, having worked with a number of rather dissimilar species within the group, I feel more familiar with this genus. The genus Erwinia, which is not considered in this article, is composed of few species and appears to be a fairly well-defined group.

The ideal method in studying and analyzing a genus is to obtain all the species and grow them in pure culture under identical conditions. There is, however, one great difficulty, namely, that but a very small percentage of these species could be secured at present. Consequently, another method was sought and the one used here is that set forth by Rahn (1916), which is based on the assumption that in any well-defined group many of the primary characteristics are identical. Rahn has demonstrated that certain correlations exist in the natural groups and has pointed out those characters on which separation and divisions may be based. He used the description of species given by Migula and by Lehmann and Neumann as the basis of his work. In the following work with the plant pathogenes the procedure employed by Rahn has been followed more or less.

In following this method of analysis one primary weakness arises. One is forced to accept the descriptions of species of a great many investigators where the technique varies not only with the time but with the different laboratories. Frequently this has been overcome, however, when several persons have worked on the same organism, and a composite picture from the various descriptions can be drawn.

Bergey in the second edition of his "Manual of Determinative Bacteriology" lists 39 species of Phytomonas.[1] In table 1, I have listed 77 species, and this is not entirely complete. For certain species, the names of which appear in literature, I have been unable to find a description and have omitted them. This type of omission, however, is but occasional.

[1] The third edition of this manual will contain descriptions of many more species of this genus.

Then, there were several species which, although described as of this genus, apparently do not belong there. As an example, I may mention *Phytomonas dissolvens* Rosen which, with the exception of its polar flagella, stained by a method as yet not divulged, has more characteristics of the Erwinia group. This staining method, too, would place *E. amylovora* (Burrill) Com. S. A. B. in the genus Phytomonas, but it has been omitted in this table.

Varieties have not been added to the list since it was felt that they would disturb the ratios of characters. Most varieties have been described mainly on pathogenicity and not on cultural characteristics. From another point of view, it is true that some of these omitted varieties are as important pathologically as or more so than the original species. *Phytomonas phaseoli* var. *sojense* (Erw. Smith) Hedges, *Phyt. medicaginia* var. *phaseolicola* (Sackett) Burkholder and the several varieties of *Phyt. translucens* Smith, Jones and Reddy might be mentioned. It is likely that certain species listed in table 1 are synonyms or only varieties; that is, they differ only in pathogenicity. *Phytomonas sojae* Wolf and *Phyt. stizolobii* Wolf probably belong to this case. *Phytomonas rhizoctonia* Thomas has been avoided in the table since it is felt that, like *Phyt. stizolobii*, under certain conditions it might be motile. At least this organism is quite different from the other nonmotile forms. *Phytomonas viridifaciens* Tis. and Will. has been considered a synonym of *Phyt. vignae* Gar. and Ken.; *Phyt. citrareifaciens* Lee and *Phyt. cituputeale* C. O. Smith have been shown by Miss Bryan (1928) to be identical with *Phyt. syringae* van Hall. There appear to be some differences in the descriptions of the pathogene as given by the three authors, but this may be due merely to technique or to fluctuating characters. Miss Bryan has done a commendable piece of work and more like it is needed. Due to a footnote in Gardner and Kendrick's article, "The Bacterial Spot of Tomato" (1921), a supposition has crept into phytopathological literature that *Phyt. exitosa* Gar. and Ken. is a synonym of *Phyt. vesicatoria* Doidge. The organisms differ in reaction to the Gram stain and in sugar fermentations, and these appear to be sufficient to separate them as distinct species.

In a search through the literature it was rather astonishing to find what few characters had been determined for some of our fairly common species. Outside of its pathogenicity, we know very little concerning *Phyt. juglandis* Pierce. *Phytomonas phaseoli* (Erw. Smith) Bergey et al. was named in 1898, but it was not until Rapp (1920) and later Hedges (1924 and 1926) worked on the species that we had an adequate description of it. The description of *Phyt. beticola* (Smith, Brown and Townsend) Bergey et al. given in 1911 is strikingly different from that given by Miss Brown in 1928. In

TABLE 1.—*Giving characters of 77 members of the genus Phytomonas*

Phytomonas	Agar pig.	Mot.	Gram	Lit. milk				Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	C.
				Curd	Ac.	Alk.	Pep.										
alboprecipitans	–	+	–			+	+	+	–	–	–	–	+	–	–	+	+
agropyri	yellow	–	W+		+W		–	+W	+	+	+	–	–	–		+	+
amaranthi	yellow	+	–			+	–	+				–		–		+	
andropogoni	–	+										–	–			+	
angulata	green	+	–			+	+	–	+	+	–	+	–	+		+	–
apii	–	+	–			+	+	–	+	+	–	+	–	–		+	
aptata	green	+	–			+	+	–	+	+	–	+	–	+	–	+	–
atrofaciens	green	+	–			+	+	+W	+	+	–	+	–	+W	+W	+	+
avenae	–	+	–	curd	+		–	–	+	+	+	+	+	–		+	
barkeri	–	+	+			+	+	+W	–	–	–	+	–	–			–
beticola	yellow	+	W+			+	+	+W	+	+		+	+	–	+	+	+
bowlesii	green	+	–	curd		+	+		+	–	–	+	+	+	+	+	–
campestre	yellow	+	–			+	+	+	–	–	–	+	–	+	+	+	–
cerasi	green	+	–					–	+	+	–	+	–			+	
cannae	–	+	–			+	+	+W	–	–	–	+	+	–	+	+	+
cichori	?	+	–					–				–	–	–			
citri	yellow	+	–			+	+	+	+	+	–	+	–	–		+	
coronafaciens	–	+	–	S. curd		+	+	+W	+	+	–	+	–	–	–	F	+
curcurbitae	yellow	+	–	curd			+	+W				+	–				

TABLE 1—(*Continued*)

Phytomonas	Agar pig.	Mot.	Gram	Lit. milk				Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	C.
				Curd	Ac.	Alk.	Pep.										
delphinii	green	+	–			+	+	+W	+	+	–	+	–	–	–	+	+
destructans	–	+	+					+	+	+	+	+	+			F	
erodii	green	+	–		+		+		+	+	+	+	–	+	–	+	
exitosa	yellow	+	–		+		+	+	–	–	–	+	–				
flaccumfaciens	yellow	+	+		+		+W		+	+	+	+W	–	–	–	+	
glycinea	–	+	–	curd		+	+	–	+	+	–	–	–	+		?	+
gummisudans	yellow	+	–	S. curd	+W		+	+W	+	+	–	+	–	–	+	+	+
hibisci	–	+	–				+					+	+W			+	
hyacinthi	yellow	+	–			+	+	+	+	+	–	+	–	+	+	+	–
holci	green	+	–				+	–	+	+	–	+	+	–	–	+	+
insidiosa	yellow	–	+	S. curd	+		–	+	+	+	+	+	–	–	–	+	
intybi	?	+	–					–				+	+				
juglandis	yellow	+						+				+				+	
lachrymans	green	+	–			+	+	–	+	+	–	+	–	+W	–	+	+
maculicola	–	+	–			+	–	+W	–	–	–	+	–	+W	–	+	
malvaceara	yellow	+	–	curd		+	+	+	–	–	–	+W		–	–	+	–
marginale	green	+	–	S. curd			+	+W	+	+	–	+	+	–	–	+	+
marginata	–	+	–	S. curd	+		+,	–	+	+	+	+	–	+W	+W	+	+
martyniae	green	+	–	S. curd	+W		+	–	+	+	–	+	+	–	+	F	+

TABLE 1—(*Continued*)

Phytomonas	Agar pig.	Mot.	Gram	Lit. milk				Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	C.
				Curd	Ac.	Alk.	Pep.										
matthiolae	–	+	–	curd	+		–					+			–	+	
medicaginis	green	+	–			+	–	–	–	–	–	–	–	–	–	+	
mellea	yellow	+	–	curd		+	+	–	–	–	–	+	–	–	–	F	+
michiganensis	yellow	–	+	curd	+W		–	+W	+	+	+	+W	–	–		+	
mori	–	+	–			+	+	+W				–	–	–		+	–
nectarophila	green	+	–				+		+	–	–	–	–	–		F	+
panici	–	+	–			+	+	+	–	–	–	+	+	–	+	+	+
papulans	–	+	–	S. curd		+	+		+	+	–	+				+	–
pelargoni	–	+	–	S. curd		+	+	+W	–	–	–	+	–	+W	+	+	+
phaseoli	yellow	+	–			+	+	+	–	–	–	+	–	–	–	+	
pisi	–	+	–	S. curd		+	+	–	+	+	–	+	–	–	–	+	–
proteamaculans	yellow	+	+	S. curd	+		+	+W	+	+	–	+				F	–
pruni	yellow	+	–	S. curd			+	+W	+	+	+	+	±	+W		+	+
peurariae	green	+	–			+	+	+W	+	+	–	+	–	–	–	+	–
pseudozoögloeae	yellow	+		curd	+		–		+	+	+	+					
rathayi	yellow	–	+		+		–	+W	+	+	+	+	–			+	+
rubrilineans	yellow	+	–			+	+	–?	+	–	–	+	+	–	–	F	–
savastonoi	–	+	–			+	–	+W	+	+	–	–	–	+W		+	

TABLE 1—(*Continued*)

Phytomonas	Agar pig.	Mot.	Gram	Lit. milk				Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	C.
				Curd	Ac.	Alk.	Pep.										
semina	–	+	+			+	+	–	+	+	–	+	–			F	+
sojae	–	+	–			+	–	+W	–	–	–	–	–	–		+	+
solonaceara	–	+	–			+	+	–	–	–	–	±	+	–		+	–
solaniolens	yellow	+			+		–	+W	–	–	–	–	–				
stewarti	yellow	–	–		+		–	+W	+	+	+	–	–	–	–	+	
stizolobii	–	+	–			+	–	–	–	–	–	–	–	–	–	+	+
striafaciens	–	+	–	S. curd		+	+	+	+	+	–	+	+W	–	+	+	+
syringae	green	+	–	S. curd		+	+	+W	+	+	–	+	–	–	–	F	–
tabaca	–	+	–			+	–	–	+	+	–	+	–	–		+	–
teutlia	–	–	+				–			+		–	–				–
tolaasii	green	+	–	curd		+	+	–	+	–	–	+	+	+W		F	–
translucens	yellow	+	–	curd	+		+	–	+	+	+	+	–	+W		+	+
trifoliora	green	+	–			+	–	+W	+	+	–	–	–			+	+
tritici	yellow	+					–		+		+W	–	+				
tumefaciens	–	+	–	curd		+W	–	+W	+	+	–	–	–	+W	+	+	
vasculara	yellow	+	±			+	–	+W	–	–	–	±	–	–		+	
vesicatoria	yellow	+	+		+		+	+W	+	+	+	+	–	–		+	+
vignae	green	+	–			+	+	–	+	+	–	+	–	–	–	+	

TABLE 1—(*Continued*)

Phytomonas	Agar pig.	Mot.	Gram	Lit. milk				Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	C.
				Curd	Ac.	Alk.	Pep.										
viridilivida	green	+	−			+	+	−			−	+	−	+		+	
vitians	yellow	+	−	curd		+	+	+W	−	−	−	+	−	+W	+	+	+
woodsii	?	+				+	−					−	−				

[a] A brief explanation of the above table follows. Under "Agar pig.," pigment production is listed on agar only. A dash (−) designates a white or colorless form; yellow is any shade from a cream yellow to a deep yellow; and green refers to the fluorescent pigment produced and dissolved in the media. Mot. is motile and Gram refers to the Gram stain. Under milk there are four columns: Curd; S. for soft; Ac. for acid; Alk. for alkaline; and Pep. for peptonization. With reference to peptonization it should be stated that descriptions as a rule have reported milk cleared (+) or not cleared (−), so there may be some doubt here. Star. stands for starch and plus denotes that it is digested; W, if weakly so. Under the three sugars listed (+) means that acid is produced; Gel. is an abbreviation for gelatin and Nit. for nitrates. A plus under the last-named denotes that they are reduced to nitrites. Ind. stands for Indol production and is followed by H_2S production. A plus under Aër. means an aërobe, and F a facultative anaërobe. C. refers to capsule production.

examining table 1 a number of forms may be found for which we know little concerning their cultural reactions. Too many species have been described on the basis of pathogenicity to some host, with a few cultural and morphological characteristics which are slightly more than sufficient to place them in a genus. Work of this type simply lays foundations for synonyms. It would be much better for all concerned, and especially for future students, if a sufficient number of characters should be determined to compare the organism with other members of its genus and cross inoculations made to ascertain whether it is a new form or an old form on a new host.

The description of the characters of many species, too, has been vague. In many cases, especially in the sugar broths, all the shades of Ridgway and all the degrees of cloudiness and turbidity have been noticed, without considering that these no doubt would vary with temperature, hydrogen-ion concentration, and other factors not mentioned. There are certain instances in which the most or only important point, namely, whether or not a given sugar was fermented, is not stated. In preparing table 1, I have been forced at times to make a guess concerning certain characters. In the list of titles appended to this paper one may easily find where my data have been obtained.

Sixteen characters were used in this table of species. They comprise all but one of the primary characteristics and a few of the secondary ones listed in the descriptive chart for 1924 prepared by the Committee on Bacprimary characteristic omitted is that of spore formation: This character teriological Technic of the Society of American Bacteriologists. The one does not exist among the bacterial plant pathogenes. The table is valuable in showing what we know at present concerning the characteristics of the species of this genus. Further work is needed in filling up the gaps and working over certain of the characters. In many instances the cultural methods used by various authors in dealing with the sugars would fail to disclose a small amount of acid produced.

In table 2 the methods of Rahn are followed, and the percentages of the characteristics are given for the entire genus and for various groups in this genus. While there are 77 species dealt with, the percentages are seldom based on this number but on that of species on which information is given on the characteristic under consideration. This varies and is usually somewhat short of 77. Consequently a definite series of percentages is not to be expected in the table. The figures in the group column refer to the number of species found in that group. All other figures in the table are percentages.

Table 2 is large and consists of many figures. To point out all correlations and lack of such would require space and would only be confusing.

TABLE 2.—*Percentage distribution of characters in various groups of species within the genus Phytomonas*[a]

Group	Pig.	Mot.	Gram	Milk			Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	Cap.
				Acid	Alk.	Pep.										
Total 77	Y 38 G 25 – 37	92	18	25	75	69	64	72	67	22	76	25	30	40	83	61
Nonmotile 6	Y 83 – 17	–	83	100	0	0	100	100	100	100	50	0	0	0	100	75
Motile 71	Y 33 G 28 – 39	+	11	21	79	75	61	69	62	16	77	28	31	42	82	60
Gram + 13	Y 69 – 31	61	+	63	37	50	91	83	91	63	84	16	0	33	72	66
Green fl. 19	–	100	0	14	86	88	38W	94	77	6	83	27	48	25	80	50
Colorless 28	–	100	15	12	88	65	56	59	61	13	68	30	32	50	88	61
Yellow 28	–	82	33	54	46	63	84	68	62	42	81	17	25	45	87	62
Yellow 13	–	100	8	31	69	85	85	38	31	0	92	9	30	57	75	37
Pep. + 49	Y 35 G 30 – 35	100	10	19	81	+	64	71	63	13	91	28	36	44	80	60
Pep. – 22	Y 48 G 9 – 43	77	33	47	53	–	76	66	66	40	41	10	21	14	100	75

TABLE 2.—(*Continued*)

Group	Pig.	Mot.	Gram	Milk			Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	Cap.
				Acid	Alk.	Pep.										
Star. + 14	Y 69 – 31	92	16	18	82	82	+	45	45	18	82	30	20	50	91	66
Star. +W 27	Y 46 G 25 – 29	85	29	32	68	60	+W	69	69	24	75	14	30	50	91	75
Star. – 23	Y 9 G 43 – 48	100	4	16	84	80	–	80	75	30	83	32	38	36	80	53
Sugar +++ 14	Y 71 G 7 – 22	65	54	92	8	70	72	+	+	+	86	36	36	20	91	100
Sugar ++– 27	Y 15 G 37 – 48	100	7	12	88	92	54	+	+	–	85	16	38	40	81	60
Sugar ––– 18	Y 44 G 6 – 50	100	12	11	89	66	77	–	–	–	72	22	25	45	93	70
Gel. + 58	Y 40 G 26 – 33	95	19	27	73	83	62	75	67	23	+	30	32	41	82	60
Gel. – 19	Y 30 G 17 – 53	84	13	23	77	19	71	61	53	23	–	11	23	20	92	77
Nit. + 18	Y 23 G 31 – 46	100	12	18	82	87	57	75	57	26	94	+	27	75	75	61

TABLE 2.—(*Continued*)

Group	Pig.	Mot.	Gram	Milk			Star.	Dex.	Suc.	Lac.	Gel.	Nit.	Ind.	H_2S	Aër.	Cap.
				Acid	Alk.	Pep.										
Nit. – 52	Y 38 G 26 – 36	88	20	27	73	65	63	69	69	19	69	–	38	29	88	66
Ind. + 19	Y 26 G 37 – 37	100	0	11	89	84	43	76	65	21	84	16	+	63	89	61
Ind. – 41	Y 38 G 24 – 38	90	19	27	73	72	66	66	61	20	75	33	–	25	84	63
H_2S + 14	Y 36 G 21 – 43	100	7	21	79	93	84	64	61	8	93	43	57	+	93	84
H_2S – 21	Y 28 G 43 – 28	90	10	25	75	71	59	70	65	20	81	15	20	–	81	61
Fac. An. 10	Y 30 G 40 – 30	100	60	25	75	100	50	90	60	10	90	44	28	20	–	55
Cap. + 28	Y 36 G 25 – 39	89	18	28	72	78	70	71	64	26	75	28	32	55	78	+
Cap. – 18	Y 24 G 41 – 35	94	17	6	94	89	50	75	59	0	89	31	33	28	75	–

[a] All figures in the table are percentages with the exception of those in the first column, where they refer to the actual number of species in each group.

Furthermore, upon examining the table closely all these correlations appear to be the result of the occurrence of several well-defined groups which appear almost intact in a number of the divisions listed in table 2. These definite groups will be pointed out and emphasized. First, however, one should look at the genus and note the general lack of correlations of characteristics which exist in it as a whole. Outside of motility and the reaction to the Gram stain, the percentages are neither high nor low. Most anything may be expected within the genus. In other words, it does not constitute a well-defined group of organisms. The reason for this confusion, one may assume, is the fact that the genus is composed of several natural groups, and that order may be obtained only by determining what they are. One conclusion which might be arrived at hastily is that the combination of the nonmotile with these motile forms has probably caused a disturbance. There are, however, only 6 of these nonmotile species listed in table 1, and these hardly could be expected to change the percentages to any great extent. Nevertheless, it will be seen in table 2 that these six species are a very closely related group of pathogenes; more so than one would expect. Should they, then, have been placed with the motile species? From examining them as a separate nonmotile group, one would say probably not; but their removal does not appear to improve matters, since it may be seen that the percentages of the 71 motile species do not deviate to any extent from the percentages of the entire genus. It still remains a group of many rather unrelated types. The question then arises whether any of the motile species are related to this nonmotile group. A search through table 1 reveals the fact that certain forms do exist which, but for their character of motility, fit in very nicely. The two most outstanding species of this group are the yellow forms, *Phyt. flaccumfaciens* Hedges and *Phyt. vesicatoria* Doidge. Besides these, several other less closely related forms are to be found, but the addition of these to the group would not materially lessen the high percentage of the majority of characters. Disregarding these outlying forms, however, one finds here eight species which can be considered the center or nucleus of a natural group of bacteria, but a group which can not be defined entirely on the absence of flagella. The Gram reaction, the ability to ferment lactose, and the ability to produce a yellow pigment are also important characters. No one character can be used to differentiate the group, and for convenience it might be referred to as the *Stewarti* group from one of its earliest described species. An intensive cultural study of these forms, no doubt, would produce results of importance.

The next character used to differentiate groups in table 2 is that of pigment formation. This is a character which has been used before by various investigators to separate genera of bacteria but with varying amounts of

success. In the genus Phytomonas there are forms producing a yellow pigment, others a green flourescence, and still others which are nonchromogenic. An attempt has been made to separate the 77 species listed in table 1 on this basis. There have been described 28 yellow bacterial pathogenes, but when these are placed together in table 2 it may be seen that they are in no sense a natural group. If one considers, however, that the *Stewarti* group constitutes approximately one third of these chromogenic forms, their heterogeneity is not surprising. If, however, one removes from the 28 yellow species those forms which ferment lactose and those the descriptions of which are so limited as to make work with them difficult, 13 species remain. These are listed in table 2 and appear to be a natural group, but one not so well-defined as the *Stewarti* group. This new group could be characterized as composed of species which are yellow motile forms that are Gram-negative, active in peptonizing milk, liquefying gelatin, and digesting starch, but are not nitrate reducers. They do not ferment lactose, but may or may not ferment dextrose and saccharose. One possible error in the table is that 31 per cent of the species produce acid in milk, a character one expects to find associated with lactose fermenters. This error might be due to the preparation of the milk and the formation of some of the lower sugars through decomposition in the process of sterilization. Further working over some of the other characteristics also might raise their percentage, since a number of these species were described when our technique was considerably less adequate than it is today. In referring to this group in the remainder of this article the name *Campestre* will be applied, since this organism is representative of these 13 yellow species.

In examining both the *Campestre* and the *Stewarti* groups, one will find that there will be some difficulty in separating them along a definite line of cleavage. There appear to exist some intermediate types between the two. Rahn (1929) has pointed out that such forms occur among the bacteria and has dwelt upon the confusion that they cause in taxonomy. *Phytomonas beticola, Phyt. pruni* (Erw. Smith) Bergey et al. and *Phyt. translucens* are, no doubt, such intermediate forms between the *Campestre* and the *Stewarti* groups. They probably have a closer relationship with the latter but, if placed there, would have a tendency to lower the high percentages of certain of the characters. On the other hand, the disturbance would be even greater in the *Campestre* group. At present these species probably should remain as intermediate forms and no attempt be made to place them in one or the other of the two groups.

A further group which appears in table 2 is that of the green fluorescent forms. To any one who has worked with any of these pathogenes this is not a surprise. The similarity of these bacteria has been noted before. In table 2 they do not appear so closely related as the members of the *Stewarti* group. Nevertheless, they are a fairly well-defined group and the percentages might

appear higher if they were better understood. For instance, in table 2, 38 are shown to digest starch. This process in the green fluorescent species is a very weak one and the percentage from one point of view should approach zero. Also, it is to be noted particularly that certain forms of the green fluorescent types like *Phytomonas erodii* Lewis upset the correlations considerably, and the group would be closer knit if such forms were dropped. Eighteen species are listed here which produce a green fluorescent pigment, but there are others in this group not brought out in these tables. Chromogenesis in these studies has been determined on agar cultures, and it is known that certain of the green fluorescent types will not produce this pigment on beef extract agar, the agar usually employed by investigators. Furthermore, this ability to produce pigment is frequently lost in pure culture. For these two reasons it is felt that a number of species belonging to the group may be found with the white or colorless forms. If it were possible to find a definite medium on or in which the character of green fluorescent pigment production could always be determined, the group could be limited more readily. Uschinsky's solution might be such a medium; at least, it appears so from superficial observation.

If one eliminates from the genus Phytomonas the three groups just discussed there remain a number of colorless forms with which very little can be done. These species contain, no doubt, a number of green fluorescent bacteria, as suggested in the foregoing. Their ability to produce the pigment is possibly very weak, which accounts for its being overlooked. Also, many other of these colorless forms have a limited description, and, consequently, they are difficult to work with statistically. Too few of their characteristics are known. The best explanation to offer concerning these remaining forms of the genus Phytomonas is that a colorless group exists. This is reasonable to expect. The group, however, is not unlike the green fluorescent group in many respects, and a number of intermediate forms between the two are to be found. Statistically, this is rather difficult to prove with our present knowledge, but an examination of the colorless forms listed in table 1 points to this belief. Further work is necessary, however, to show this to be true.

The three and possible four bacterial groups existing in the genus Phytomonas would, if it were not for the character of pathogenicity, find places in several genera of the family Bacteriaceae of Bergey. The *Stewarti* and the *Campestre* groups would fall in the genus Flavobacterium, since they are both composed of species forming a yellow pigment. As has been pointed out in this article, however, the ability of these organisms to produce a yellow pigment does not appear to be a character on which to base a natural group. As far as known, no intensive work has been done on the genus Flavobacterium and it is not known whether or not it could be separated into two groups as the yellow plant pathogenes have been.

In a similar manner, the green fluorescent group of plant pathogenes would fall in the genus Pseudomonas of Bergey.[2] It is well known that many of the nonpathogenic fluorescent types are ubiquitous and are common saprophytes found living in the soil, on seeds, and on various parts of plants. In this there appears to be a relationship in habitat between the pathogenes and the saprophytes. This fact also might at least indicate the possible origin of the green fluorescent pathogenes which have arisen so suddenly and mysteriously at times.

The colorless plant pathogenes would fall into the genus Achromobacter.

One character of interest to the plant pathologist not touched upon here and possibly of great help in this work is the type of symptom produced on the plant by the pathogene. It is known that certain closely allied organisms produce similar diseases in animals. The members of the genus Pasteurella are an example of this. Similar cases might occur among the plant pathogenes. This character, however, would probably be difficult to point out since in certain bacterial diseases of plants the causal organism may produce various types of symptoms. It is a matter, nevertheless, worthy of consideration.

CONCLUSIONS

While this study has not presented any definite conclusions, it is hoped that bringing together the material and presenting it to the plant pathologist will make more apparent the difficulties and needs in this field. The article has pointed out, however, the reasons for the confusion that exists in the taxonomy of the bacterial plant pathogenes and the fault that investigators are making by looking at the subject over antiquated systems of classification and not examining the group as a whole. It has also demonstrated that certain natural groups do exist and that there probably are others which will come to light after more exact study. That these groups can be defined on single characteristics, as presence or absence of flagella, appears to be doubtful. What ranking these groups should receive can be determined only by further work. The question, too, arises as to whether the plant pathogenes should be treated separately or whether they should not find their places in the genera of the bacteria as a whole. Proof is yet to be given that pathogenicity is a character on which to separate genera, let alone one on which a tribe may be formed.

DEPARTMENT OF PLANT PATHOLOGY,
CORNELL UNIVERSITY,
ITHACA, N. Y.

[2] The genus Pseudomonas of Bergey is entirely distinct from the genus Pseudomonas of Migula. The former is characterized by the ability of its members to produce a green fluorescent pigment. The latter genus is based on the character of polar flagella possession.

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"FERN-LEAF" OF TOMATO[1]

N. MOGENDORFF

The symptom known as "fern-leaf" of tomatoes is chiefly characterized by a filiform abnormality of part of the foliage. For many years this condition has been considered as associated with a virus and as such it has often been referred to by pathologists as a symptom of ordinary tomato mosaic. At the same time, however, the common occurrence of tomato mosaic and the only sporadic appearance of fern-leaf together formed a problem which has never been fully solved. More recently it has been claimed by some investigators that fern-leaf symptoms on tomatoes may not necessarily be the result of a virus in the present sense of the word, but that these may be produced by a substance which has the nature of a toxin (22). It has also been suggested in a recent paper that fern-leaf symptoms may, in some cases at least, be of an hereditary nature (23).

The present investigation was undertaken with the purpose of determining, as far as possible, the factors governing the development of fern-leaf symptoms as resulting from virus infections. The evidence secured by Johnson (17) that fern-leaf is often associated with cucumber mosaic on tomatoes was taken as a base for further studies. Johnson was not able, however, to produce fern-leaf symptoms at will with this virus; consequently it appeared that some other factors were involved. In the present paper it will be shown that these factors are connected with the method of infection, the age of the plant at the time of infection, and with certain environmental conditions.

Since Clinton (8) carried out his cross-inoculation experiments with the tobacco-mosaic virus on tobacco and tomato, it has generally been assumed that the virus causing tomato mosaic is identical with the ordinary tobacco-mosaic virus. It was, therefore, considered advisable to study simultaneously the tobacco-mosaic disease of tomatoes for comparative purposes. This paper is consequently concerned with two virus diseases of the tomato, namely, tomato mosaic as caused by *Tobacco virus 1* (18) and tomato mosaic as caused by *Cucumber virus 1* (18). For convenience these diseases will be referred to as tobaco mosaic on tomato and cucumber mosaic on tomato.

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REVIEW OF LITERATURE

Mosaic symptoms on tomatoes were first described in 1902 by Woods (31) on plants which he had accidentally infected with tobacco-mosaic virus. It was not until 1907, however, that Clinton (8) in Connecticut reported an "infectious chlorosis" in field tomatoes, which was found to be "of the same nature as calico of tobacco." A tomato-mosaic disease occurring in greenhouses in Holland was studied by Westerdijk (30). Although she was not able to transfer this disease to tobacco, it has been assumed by some that she was dealing with ordinary tomato mosaic, while others expressed doubt about its character. The tomato-mosaic disease reported from Massachusetts by Stone (28) and later by Chapman (5) has also been interpreted as identical with tobacco mosaic. A description of symptoms produced on tomatoes by artificial inoculation with tobacco-mosaic virus was given by Allard (1). Gardner and Kendrick (12) made an extensive study of tomato mosaic as it occurs in Indiana, but they give little evidence for the identity of the disease. From their descriptions it would appear that at times more than one virus may have been involved in their studies. The descriptions of tomato mosaic as given by Neal and Barker (26), Chupp (7), and others are essentially the same as those reported by Gardner and Kendrick (12).

Tomato fern-leaf as a symptom of tomato mosaic was first described by Westerdijk (30), who states that this symptom was never observed as a result of natural infection in the field or greenhouse, but only on artificially inoculated plants. Humbert (14) states that at times string-leaf or fern-leaf was observed in Ohio on mosaic tomatoes. McCubbin (24) calls it "a symptom of somewhat rare occurrence", which is associated with tomato mosaic, while McKay (25) states that filiform leaves are unusual on mosaic tomatoes, though not rare. Berkeley (3) reports from Canada that a filiform and spindly leaf is often associated with tomato mosaic. From the literature it thus appears that "tomato mosaic" generally is considered to be identical with tobacco mosaic. Its symptoms answer, in general, the descriptions given by Allard (1) and Gardner and Kendrick (12), while fern-leaf is commonly accepted as a symptom that is frequently associated with this desease.

In more recent years, symptoms differing from those referred to above have been reported, with the result that some investigators have commenced to recognize distinct types of mosaic symptoms on tomatoes, without asserting, however, that these are caused by different viruses. For instance, Bewley (4) distinguishes five main types of mosaic symptoms on tomato foliage among which he lists the "tendril type", which is characterized by a reduction of the lamina and the production of tendril-like leaves. These various symptoms may, according to this investigator, be found

singly on individual plants or together on the same plant. Although granting that a considerable amount of investigation is still necessary, Bewley (4) is inclined to believe that "these symptoms are manifestations of the same disease, their appearance being governed by a number of factors, chief of which are the environmental conditions under which the host plant is grown, and the degree of resistance exhibited by it." Weber and Ramsey (29), working in Florida, recognize three types of tomato mosaic, namely, the linear type with filiform leaves, the crinkle type, and the mottle type. The linear type is reported as rather uncommon, while the crinkle type is by far the most common type of tomato mosaic in Florida. Apparently on the basis of symptoms, Poole (27) distinguishes three virus diseases on the tomato, namely, streak, mosaic, and the filiform disease. Johnson (18) reports eleven virus diseases affecting the tomato, which he obtained by inoculation with eleven distinct viruses. This would point to the possibility of great complications in the symptomatology of tomato-virus diseases and might explain some of the existing confusion.

MATERIALS AND METHODS

The experimental work was carried out in the University of Wisconsin greenhouses at Madison, Wisconsin, between the months of September and June. The plants were started in flats in a warm greenhouse at 28–32° C. and transplanted into compost soil in four-inch pots. The common tomato (Marglobe variety) was used in the majority of the experiments, but in some cases the "potato-leaved" or large-leaved variety, Hudson Valley Maid (*Lycopersicum esculentum* Mill. var. *grandifolium* B.), served as host plant.

The minimum number of plants inoculated for each treatment was five, and in many cases units of ten plants were used. Each unit was accompanied by at least two and usually four or five noninoculated control plants. Great care was taken to use healthy plants of the same age and of uniform size. The plants ordinarily were inoculated by the cotton-needle method when they were about 5 cm. high, at the time when the third leaf (exclusive of the seed leaves) was just emerging.

Since tobacco is a better source of inoculum than tomato, the inoculum was prepared by pressing the crushed, fresh leaves of cucumber-mosaic or tobacco-mosaic tobacco through a piece of cheesecloth. The expressed juice was used for inoculation directly after extraction. The tobacco-mosaic virus used for inoculum was collected in the field and identified as *Tobacco virus 1* (18). The cucumber-mosaic virus was kindly furnished by Dr. Doolittle of the U. S. Department of Agriculture; this virus answered the description of *Cucumber virus 1* (18). If young tobacco plants, kept under greenhouse conditions at 30° C., are inoculated with

Tobacco virus 1 and with *Cucumber virus 1*, it is easy for the trained eye to distinguish between the two viruses, judging by symptoms only. Therefore, after inoculating each series of tomatoes, five tobacco plants were inoculated with the same inoculum, in order to check the identity and purity as well as the virulence of the virus employed.

EXPERIMENTAL RESULTS

After preliminary experiments had corroborated Johnson's (17) findings concerning the association between fern-leaf symptoms and cucumber mosaic on tomato, special efforts were made to study the symptomatology of this disease. A fair percentage of infection was usually obtained in these preliminary experiments with *Cucumber virus 1*, but only very few or none of the infected plants would show typical fern-leaf symptoms. In most cases the disease revealed itself only by stunting and a general chlorosis of the host plant, sometimes accompanied by a faint mottling of the foliage and slight malformation of the leaflets. Besides the common tomato, four different botanical subspecies were used, which are classified by Bailey (2) as follows: Large-leaved tomato (*L. esculentum* var. *grandifolium* B.), Cherry tomato (*L. esculentum* var. *cerasiformi* B.), Pear tomato (*L. esculentum* var. *pyriforme* B.), and Upright tomato (*L. esculentum*

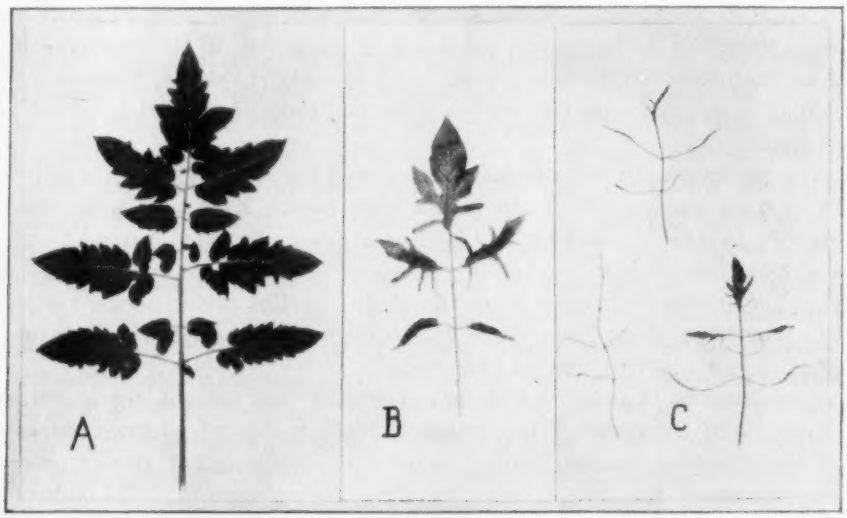

FIG. 1. A. Healthy tomato leaf from control plant. B. Tomato leaf showing approximately maximum malformation secured with the tobacco-mosaic virus; the common and characteristic symptom is mottling only. C. Tomato leaves showing fern-leaf symptoms; these are produced only sporadically with wound inoculations but may be produced at will by aphid transmission of the cucumber-mosaic virus.

var. *validum* B.). All five types of tomatoes were found to be equally susceptible to both the tobacco-mosaic virus and the cucumber-mosaic virus. Under the same environmental conditions, the symptoms produced by either virus on these varieties were essentially similar, and consequently it was assumed that the development of fern-leaf symptoms did not depend on the varietal characteristics of the host plant.

In order to facilitate the discussion of the various symptoms brought about by changes of environment, etc., the symptoms of both mosaic diseases will be described as they appear on tomato plants inoculated in the third-leaf stage and kept at a greenhouse temperature of 18–23° C.

Tobacco mosaic on tomato. The incubation period for this disease is usually about ten days at temperatures of 18–23° C. The symptom development can conveniently be divided into three successive stages, characterized, respectively, by stunting, malformation, and mottling. The early stage of the disease is marked by stunting of the whole plant and by folding or rolling of the young leaflets along their midribs. This and the slightly pendant position of the leaves give the plant a spindly appearance. In the next stage a dark green bulging appears along the veins of the leaflets together with a chlorosis of the adjoining areas. At the same time malformation of the leaflets becomes apparent as they flatten out. This malformation consists of a transformation of the normally-rounded lobes of the leaflets into delicate spine-like lobes. The laminae of the leaflets are narrower than normal, and the smaller ones may occasionally be reduced even to filiform structures. The dark green bulging is usually very conspicuous in these malformed leaves (Fig. 1, B). In the foliage appearing during the third stage, the dark green bulging and malformation are replaced by a more or less diffuse mottling. Pale green or yellow areas appear between the veins of the leaflets, while the main veins are bordered by dark green zones. In the case of the potato-leaved varieties, the young leaves are not folded in the early stage, but, on the other hand, the dark green bulging along the veins is here more conspicuous than with the other varieties.

Cucumber mosaic. In case typical fern-leaf symptoms develop, the first characteristic symptom of this disease, appearing about ten days after inoculation, is the spindly appearance of the young leaves in the terminal bud. These leaves twist around in corkscrew fashion; the young leaves, which in a normal plant start to unfold at an early stage, remain folded, curve downward, or curl up in spirals. Chlorosis of the older leaves, especially along the veins, is also an early symptom. About three weeks after inoculation, the spindly leaves have unfolded, and typical distortions are formed which result in filiform leaves (Fig. 2). These leaves, of which two or three orginate from the terminal bud, are characterized by marked reduction of the lamina, often to such an extent that only the midrib is left

FIG. 2. Left: Tomato plant showing fern-leaf symptoms resulting from inoculation with cucumber-mosaic virus. Right: Healthy tomato plant.

(Fig. 1, C.). Besides the filiform leaves developed in the terminal bud, several others may be formed in the leaf axils. A marked rolling and folding of the leaves as well as a characteristic mottling often accompany these early symptoms. About five weeks after inoculation, when the filiform leaves are well developed, another type of symptom becomes apparent. This symptom is conspicuous by the excessive number of lateral leaflets produced. For these leaves, which may also show either mottling or general chlorosis, the name "polypinnate" leaves is suggested (Fig. 3, B, C.). No study was made of the pathological anatomy of the polypinnate leaves, but observa-

tions of intermediate stages of this condition make it appear that the excessive number of leaflets originates from an excessive branching of the vascular system of larger leaflets, while these are still in the embryonic stage. After two or three polypinnate leaves have been formed, the subsequently-developing terminal leaves usually appear more normal in their gross morphology, although mottling and chlorosis still remain. An early branching of the main stem and the prolific growth of axillary buds give the plant a bushy appearance. This and the general chlorosis and stunting are, to the casual observer, the most conspicuous symptoms.

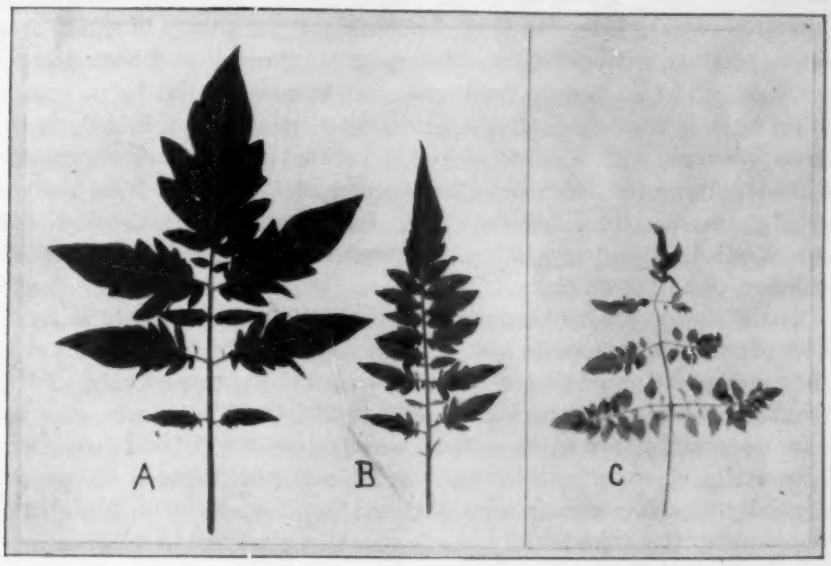

FIG. 3. A. Healthy tomato leaf from control plant. B. Polypinnate leaf from plant infected with the cucumber-mosaic virus. This abnormality is even more characteristic of infection with this virus than is the filiform leaf condition. C. The polypinnate condition, produced by the cucumber-mosaic virus, extended to the lateral leaflets.

It is usually not difficult to distinguish between the filiform leaves of a cucumber-mosaic tomato plant and the malformed leaves of a tobacco-mosaic plant of the same age. The filiform leaves show decidedly less dark green bulging or none at all, and they do not stand out so rigidly, but rather hang down flaccidly or curl around like tendrils. The mottling produced by the cucumber-mosaic virus on tomato also differs from the mottling resulting from tobacco-mosaic-virus infection. The color contrast of the adjoining areas is much less conspicuous in the case of cucumber mosaic. Instead of the larger dark and pale green areas associated with tobacco mosaic, the foliage reveals a delicate mosaic pattern of minute, sharply-defined, angular

spots of two shades of green, intensified green usually being absent. This mottling and the marked general chlorosis may often be of help to distinguish between these mosaic diseases.

THE RELATION OF ENVIRONMENTAL FACTORS TO SYMPTOM EXPRESSION ON TOMATO

From the preceding inoculation experiments it seemed more likely that the production of fern-leaf symptoms would be associated with certain environmental factors or combinations of factors, and it was, therefore, deemed desirable to study the behavior of young tomato plants inoculated with *Cucumber virus 1* under various environmental conditions in order to ascertain whether any such correlation existed. Since it had been reported by others (21) that fern-leaf symptoms could be produced by inoculation with a filtrable fraction of "tomato-mosaic" virus, which ordinarily is considered identical with *Tobacco virus 1,* a parallel series of experiments was conducted, using the latter virus for inoculum. Being considered the most probable environmental factors to affect symptom expression, the following were studied: soil temperature, atmospheric temperature, atmospheric humidity, and light intensity.

The Wiconsin constant-temperature tanks (20) were used to study the effect of soil temperature on symptom expression. The temperature of the soil was kept at approximately 15, 25, and 35° C., respectively, and the greenhouse temperature varied from 19 to 23° C. The plants were kept under observation for at least four weeks after the date of inoculation. Three series of experiments were carried out with tobacco mosaic, and essentially the same results were obtained in all cases. The effect of the soil temperature on the healthy plants was very marked. A vigorous plant was obtained at 35°, a less vigorous but well-developed plant at 25° C., while a much-stunted plant resulted at 15° C. So far as the mosaic plants were concerned, no unusual symptoms were produced. The symptoms at the three soil temperatures differed mainly in their rate of appearance and development, the most marked difference being between the plants grown at 15 and those at 25° C. A temporary partial or total masking of symptoms was obtained at soil temperatures of 25 and 35° C., which is in agreement with the findings of Johnson (15) and Dickson (9) for tobacco mosaic on tobacco. In general, it may be concluded that the results of these experiments are the same as those obtained by Johnson (15); *i.e.,* the effect of soil temperature is apparent only in so far as it affects the growth of the host plant.

The effect of soil temperature on cucumber-mosaic symptoms on tomatoes was also studied, but the results of these experiments did not permit the

drawing of definite conclusions, due to the low percentage of infection obtained.

The temperature and humidity control chambers devised by Johnson (19) were employed for the study of atmospheric relations. Three chambers with approximate temperatures of 15, 25, and 35° C., respectively, were used to study the effect of air temperature. The plants were grown in the greenhouse and removed to the chambers directly after inoculation. They were kept in the chambers for two weeks and then returned to the greenhouse for two more weeks of observation.

Besides being etiolated by the poor light conditions in the chambers at the time of the year when the tests were conducted, both healthy and diseased plants were also markedly affected by the air temperature. The plants grown at the medium temperature were the most vigorous; at 15° little growth took place and the plants were of light green color; while at 35° C. the plants were spindly with grayish green foliage.

The results of three series of chamber experiments with tobacco mosaic were of such uniformity that they may be summarized in a few statements. All inoculated plants became mosaic. At 15° C., the incubation period was 10 to 15 days; at 25 and 35° C., it was six or seven days. During the two weeks that the plants were kept in the chambers, typical symptoms developed only at the medium temperature. At the low temperature, the incubation period either exceeded two weeks or only the very early symptoms of the disease developed in the chamber. The foliage of the plants kept at 35° C. developed a dark green, sharply-defined mottling instead of dark green bulging. A week after removal from the chambers, the low- and medium-temperature plants showed typical tobacco-mosaic symptoms, while gradually these symptoms also started to appear on the new growth of the stunted and spindly, high-temperature plants.

In the case of cucumber mosaic the results were very inconsistent; the percentage of infection was variable and the incubation period exceeded two weeks, so that the effect of the temperature on the symptom expression could not be determined. In order to provide better light conditions than those prevailing in the chambers, a series of tomato plants was placed in temperature-controlled greenhouse sections directly after inoculation. The temperature fluctuations here were more marked than in the chambers, but the deviations usually did not exceed more than a few degrees Centigrade. The disadvantage of the variability in temperature was greatly compensated by the better light conditions, which permitted the exposure of the plants to the various temperatures for long periods without disturbing their photosynthetic activities. The average temperatures employed were 15, 20, 25, and 30° C., respectively. A fair amount of infection with the cucumber-mosaic virus was obtained at all temperatures and more or less typical filiform symptoms

were observed at 15, 20, and 25° C. The plants kept at 30° C. showed only semifiliform symptoms; their leaves were malformed with narrow laminae, but their transformation was not such that the term filiform was warranted.

The relation of atmospheric humidity was studied by means of the same temperature- and humidity-control chambers. The temperature of all three chambers was kept at 30° C., while relative humidities of 40, 65, and 85 per cent, respectively, were maintained. Three experiments were carried out with each mosaic disease, but in no case could any effect be detected either on the symptoms of tobacco mosaic or on those of cucumber mosaic on tomato.

In some of the experiments carried out in the chambers, necrosis was observed on the inoculated plants, which could not be attributed either to the humidity or to the temperature factor. It was noticed that this necrosis was more marked in the experiments carried out during November and December when light conditions were very poor than in the experiments performed during the succeeding months. This led to the belief that light intensity associated with mosaic disease might be the cause of the observed necrosis.

Through the kindness of Dr. W. E. Tottingham, the writer was enabled to make use of two chambers in which light as well as temperature and humidity could be controlled. Five tomato plants inoculated with tobacco mosaic were placed in each chamber directly after inoculation. Five healthy plants served as controls in each chamber. A parallel set of mosaic and healthy plants was kept in a warm greenhouse (approximately 30° C.) under natural light conditions. The temperature in the chambers was 28 to 30° C. and the relative humidity was approximately 60 per cent. The plants, which were placed on a slowly-rotating table, received their illumination only from an artificial source for eight hours each day. One chamber was provided with four 500-watt Mazda lamps, while in the other chamber only one such lamp formed the source of illumination.

After one week the mosaic plants grown under low-light-intensity conditions showed a marked necrosis of the basal leaves, while the mosaic plants receiving 2000-watt illumination showed even less necrosis than those grown under natural-light conditions in the greenhouse. Necrosis of the seed leaves on plants of this age is a natural phenomenon occurring on healthy plants even under the most favorable conditions. The necrosis of the mosaic tomatoes as caused by poor light conditions became apparent first on the basal leaves, while gradually higher leaves also were affected. In severe cases basal stem necrosis developed, causing the plant to collapse and die as if attacked by a damping-off organism. The experiment was repeated three times with similar results. With the data on hand, it is impossible to give the exact interpretation of such phenomena, but it

might be considered as additional evidence that the disturbances caused by mosaic diseases have an important bearing on the photosynthetic processes.

From the experiments with tobacco mosaic, it can be concluded that typical fern-leaf symptoms were not produced under any of the environmental conditions tried, although the symptom expression of the disease was affected in certain cases. So far as pertains to cucumber mosaic, the experiments reported here were not always satisfactory due to the variability in the percentage of infection obtained, and definite conclusions were not fully justified. Cool atmospheric temperatures seemed favorable to the development of fern-leaf symptoms; but, on the other hand, it became evident from these experiments that the variability in infection percentage with the cucumber virus was not correlated with environmental conditions.

It was then considered possible that the method of inoculation might have a more important bearing on this point and, consequently, a series of experiments was carried out to determine if any such relationship existed.

THE RELATION OF APHIDS TO THE DEVELOPMENT OF TOMATO FERN-LEAF

For a satisfactory study of the fern-leaf symptom as it results from infection with the cucumber-mosaic virus, it was, in the first place, highly desirable to be able to obtain a high percentage of infection with this virus on tomatoes. As has been shown in the previous experiments, the percentage of infection could not be correlated either with varietal susceptibility or with changes in predisposition as brought about by environmental conditions. It was then thought possible that if the virus could be provided with a more favorable substratum by bringing it in contact more directly with specific tissues, better results might be expected. In order to investigate this point, some experiments were carried out in which the inoculum was introduced into certain parts of the plants, making a special distinction between leaf parenchyma and the vascular system. The potato-leaved variety (Hudson Valley Maid) was mainly used in these experiments because of the greater simplicity of its vascular system. Insect pins, provided with very small cotton wads, were used for inoculation instead of the rather coarse dissecting needles. Where the mesophyll was the point of inoculation, special care was taken not to injure the finer veinal structures, but naturally some injury resulted. A summary of these experiments is given in table 1 and, from the data presented, it may be seen that in Experiments 1, 2, and 6, a high percentage of infection was obtained in all cases, except where the inoculation was restricted to the seed leaves. In Experiments 4 and 5 a low percentage of infection resulted in all cases but one. It thus appears that no differences in percentage of

infection were obtained, which could be attributed to the various methods of inoculation. The great variability in the percentage of infection in the various experiments cannot now be explained, although it should be noted that Experiments 1 and 2 were carried out during April when light conditions were favorable, while all other experiments were performed during November when poor light conditions prevailed.

TABLE 1.—*Results of inoculation of different parts of the plant on the percentage of infection obtained with cucumber mosaic on tomatoes*

Experiment No.	Part of plant inoculated	Plants inoculated	Plants infected	Incubation period
		Number	Number	Days
	Seed leaves	10	2	16
	Simple leaves	10	10	10
1	Seed leaves and simple leaves	10	10	10
	Seed leaves, simple leaves, and first compound leaf	10	10	10
	Control (noninoculated)	5	0	
	Mesophyll of simple leaves	10	10	9
	Veins of simple leaves	10	10	9
2	Veins of compound leaves	10	10	9
	Control (noninoculated)	5	0	
	Veins and stem	5	5	13
3	Mesophyll	5	2	13
	Stem and petioles[a]	15	4	15
	Veins	10	2	17
4	Mesophyll	10	3	17
	Control (noninoculated)	3	0	
	Leaves[b]	5	1	10
5	Stem[b]	5	2	10
	Control[b] (noninoculated)	5	0	
	Leaves[b]	15	14	9
6	Stem[b]	15	12	9
	Control[b] (noninoculated)	4	0	

[a] Inoculated by means of hypodermic needle. [b] Marglobe variety.

While this work was in progress, it was shown by Hoggan (13) that cucumber mosaic could be transmitted by the peach aphid to tomato from tobacco (*Nicotiana tabacum* L.), *N. rustica* L., and tomato. It was then but a logical step to make a comparative study of artificial inoculation by the cotton-needle method and infection by aphids. A colony of non-

viruliferous peach aphids, *Myzus persicae* Sulz., was kindly furnished by Dr. Hoggan. A supply of nonviruliferous aphids was kept in an insect-proof cage on young, healthy cabbage plants, while another supply of viruliferous aphids on young cucumber-mosaic *N. rustica* plants was kept in another cage. *Nicotiana rustica* was found to be superior to tobacco as a host plant for the aphids. All aphid-transmission experiments were carried out in the greenhouse at a temperature of 20 to 23° C., unless otherwise mentioned. Infection was brought about by transferring leaves bearing 20 or more aphids to the plants to be infected. The aphids were allowed to feed for five or six days while the plants were kept in insect-proof cages. After this period, the plants were removed to another greenhouse to be fumigated. After fumigation, the plants were kept in a cool greenhouse (20–23° C.) for observation.

A series of experiments was carried out to study the comparative effects of aphid transmission and inoculation by wounding on the symptom expression and infection percentage of cucumber mosaic on tomato. The data presented in table 2 show clearly that striking differences resulted. Where the aphid transmission method was used, 84 out of a total of 90 plants be-

FIG. 4. A. Tomatoes infected with cucumber mosaic by means of peach aphids—B. Tomatoes inoculated with cucumber-mosaic virus by wounding (only the plant in front shows mild symptoms)—C. Control plants.

came infected, and of these, 82 showed marked fern-leaf symptoms. On the other hand, only 20 out of a total of 120 plants became infected when the plants were inoculated by the cotton-needle method and only 7 of these showed fern-leaf symptoms. (Fig. 4.) The infected plants which did not develop filiform malformations revealed their diseased condition only by

their stunted and chlorotic appearance and occasionally by mottling and slight malformations of the foliage.

TABLE 2.—*The relation of method of infection to tomato fern-leaf development*

Experiment No.	Variety	Infected by aphids			Infected by wounding			Noninoculated controls	
		Plants used	Plants infected	Plants showing fern-leaf	Plants used	Plants infected	Plants showing fern-leaf	Plants used	Plants infected
		Number	Number	Number	Number	Number	Number	Number	Number
1	Marglobe	10	10	8	5	0	0	5	0
2	Marglobe	10	9	9	10	2	1	5	0
3	Marglobe	10	10	10	45	9	1	5	0
4	Marglobe	20	18	18	20	2	2	5	0
5	Marglobe	10	9	9	10	4	0	5	0
6	Hudson Valley Maid	10	9	9	10	1	1	5	0
7	Hudson Valley Maid	10	9	9	10	2	2	5	0
8	Hudson Valley Maid	10	10	10	10	0	0	5	0
	Total	90	84	82	120	20	7	40	0

These experiments were carried out during December and January which may partly account for the extremely low percentage of infection resulting from inoculation by wounding. In the previously reported studies on environment, which were carried out under more favorable light conditions, 50 to 70 per cent of infection was often obtained, but none or very few of the infected plants developed fern-leaf symptoms. The feeding of nonviruliferous peach aphids (approximately 20 aphids per plant) on tomato plants in the third-leaf stage for two weeks produced no symptoms. Thus, positive evidence is obtained that fern-leaf symptoms on tomatoes can be produced at will by infecting young tomato plants (second- or third-leaf stage) with *Cucumber virus 1* by means of the peach aphid under the environmental conditions mentioned.

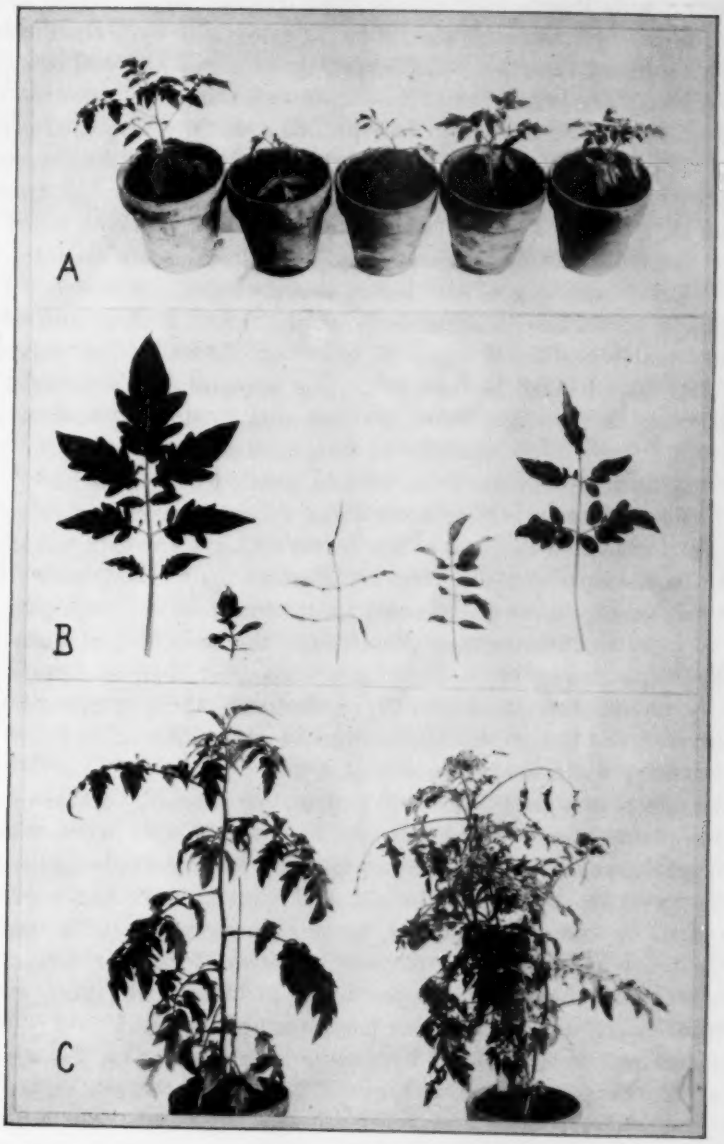

FIG. 5. A. Effect of atmospheric temperature on the development of tomato fern-leaf. Left to right: Healthy plant (grown at 20° C.); cucumber-mosaic tomato plants grown at 15, 20, 25, and 30° C., respectively. B. Leaves taken from plants shown in A. C. Left: Healthy tomato plant. Right: Cucumber—mosaic tomato plant showing early branching of main stem, prolific development of axillary buds, and filiform foliage.

If such plants infected by aphids were transferred to larger pots and allowed to grow to maturity, the following symptoms were observed: An early branching of the main stem frequently occurred and was usually followed by secondary branching. The plants were stimulated towards formation of axillary buds, which, by their prolific growth, contributed considerably to a bushy appearance of the plant. (Fig. 5, C). Mottling was always present, but a marked chlorosis and stunting were often more conspicuous symptoms. The plants blossomed, but most blossoms failed to set fruit or the fruit was shed prematurely. The leaves were malformed and often filiform; crinkling of the leaves was a common symptom. Besides crinkling, a spiral-like twisting both of the whole leaflets and of their markedly malformed lobes could be observed. More or less polypinnate leaves were found in all new growth. The polypinnate characteristic and the marked crinkling of the leaves, together with the inconspicuous mottling and prolific growth of new shoots, make cucumber mosaic on tomato relatively easy to distinguish from tobacco mosaic on the same host. In the case of tobacco mosaic neither tendril-like, filiform leaves nor polypinnate leaves are formed. Crinkling of the leaves and a marked development of new shoots are special characteristics of cucumber mosaic, while distinct mottling is usually more conspicuous on tobacco-mosaic plants. It should be borne in mind, however, that diagnosis on the basis of symptoms is very difficult, if not impossible, if both viruses manifest their symptoms simultaneously on the same host plant. In that case their symptoms will be superimposed and the presence of tobacco mosaic is difficult to detect unless inoculation experiments are carried out.

If tomato plants are infected with cucumber mosaic by means of aphids after the plants have reached a height of five inches or more, much less marked malformation is obtained and in many cases the only disease symptoms observed are stunting, chlorosis, and mottling. In the transferring of the virus to these larger plants, greater numbers of aphids were used, since the peach-aphid strain employed did not thrive well on larger plants. Two experiments, however, each involving 15 inoculated plants, gave 100 per cent of infection with cucumber mosaic but no fern-leaf.

The production of fern-leaf symptoms thus depends on the age of the plant at the time of infection, and, as will be shown later, also on the atmospheric temperature. But, even when these requirements are fulfilled, the symptoms produced are not always of the fern-leaf type if the infection has been brought about by wounding. In most cases where wounding is employed as the method of infection, the only symptoms produced are mottling and slight stunting, while in other cases chlorosis or slight malformation will result, but typical fern-leaf is produced only in relatively rare instances. There are, of course, several cases known among virus diseases where aphids

have proved to be much more efficient in the production of a high percentage of infection, but the writer knows of no case where a different type of symptoms has resulted if the infection was produced by means of aphids in comparison with artificial inoculation by wounding. Although attempts have been made to determine the cause of this behavior, an explanation for this interesting phenomenon is not now available.

THE RELATION OF ENVIRONMENTAL FACTORS TO THE DEVELOPMENT OF TOMATO FERN-LEAF PRODUCED BY APHID INFECTION

Since it was now possible to obtain a high percentage of typical fern-leaf symptoms, it was considered worth while to study once more the effect of atmospheric temperature on the symptoms produced. Forty young plants were infected by means of aphids and then subjected to different atmospheric temperatures. Five plants were placed in each of four constant-temperature chambers and five in each of four temperature-controlled greenhouse sections. Two noninoculated plants also were placed in each chamber and in each greenhouse to serve as controls. All aphid-bearing plants developed symptoms and all control plants remained healthy.

The temperatures in the greenhouse sections were 12–18° C., 18–24° C., 27–33° C., and 29–32° C., respectively. At 12–18° C. growth was very slow, but, after about four weeks, more or less filiform leaves developed on two plants, while the others showed malformation, stunting, and mottling. At 18–24° C. typical fern-leaf symptoms developed on all plants three weeks after inoculation and polypinnate leaves developed about two weeks later. At 27–33° C. the symptom expression was practically the same as at 29–32° C.; no typical fern-leaf symptoms developed on any of the plants although slight distortions and narrowing of laminae occurred. At these higher temperatures excessive branching was observed as well as the formation of polypinnate leaves, while mottling of the cucumber-mosaic type was rather conspicuous.

The temperatures of the chambers were 10–11° C., 19–21° C., 24–26° C., and 27–30° C., respectively. The disease symptoms observed in the chamber were of the same order as those described above for the greenhouse, except for partial etiolation of the plants in the chambers. No growth took place in the chambers at 10–11° C.; after six weeks the inoculated plants, which were spindly and chlorotic, showed marked leaf rolling. At 19–21° C., marked fern-leaf symptoms developed, while at the higher temperatures the disease expressed itself by excessive branching, malformation, and mottling. These experiments thus show that the optimum temperature for the formation of fern-leaf symptoms lies between 18 and 22° C.; the approximate minimum is 15° C. and the approximate maximum temperature, 25° C. (Fig. 5, A, B.)

In order to determine whether atmospheric temperature would change the predisposition of the host, ten young tomato plants grown in a warm greenhouse (30° C.) and ten others grown in a cool greenhouse (20° C.) were infected at the same time by means of aphids. After fumigation, both groups were kept in the cool house. No difference was noticed either in the incubation period or in the percentage of infection produced. Typical, stunted, filiform plants resulted in both cases.

The effect of light intensity on cucumber-mosaic tomatoes was now also studied by using aphids for transmission of the virus. The experiment was performed in the same way as previously described for tobacco mosaic, except that the temperature of the chambers was now kept at 20 to 23° C. with a relative humidity of 45 to 50 per cent. All the infected plants in the high-light-intensity chamber developed typical filiform symptoms, while those kept under poor light conditions showed severe symptoms of wilting and necrosis which resulted in the death of some of the plants.

DISCUSSION

The experimental results reported in this paper may contribute to the explanation of certain contradictory results obtained by previous investigators and may clear up some of the existing confusion concerning tomato mosaic. It is of interest, therefore, to consider once more the statements found in the literature in the light of the experimental results obtained by the writer.

Westerdijk's (30) failure to cross-inoculate the mosaic diseases of tobacco and tomato which she was studying may be explained by the fact that cucumber-mosaic tomato plants served as sources for inoculum. The artificial inoculation with cucumber-mosaic virus is much more difficult than with tobacco-mosaic virus, especially when larger plants are used, as was often the case in Miss Westerdijk's work. Moreover, the cucumber-mosaic virus soon loses its virulence after extraction, which is another factor that might account for her negative results. From the illustrations in her paper, it seems very evident that she did observe both virus diseases. Figure 1 and figure 3 of her paper show mottling and malformation, very typical for tobacco mosaic; while marked filiform symptoms are reproduced in figure 5. The latter may have resulted from aphid infection.

In describing the symptoms of tomato mosaic, Gardner and Kendrick (12) state that "the leaflets may be distorted and crumpled or reduced to narrow ribbons. Severely diseased plants may be greatly stunted and bushy with a yellowish cast and the leaves so reduced as to warrant the term 'fern-leaf.' Such plants bear only stunted fruits or none at all." With these words they present an extact picture of a cucumber-mosaic

tomato plant, and this would indicate that they, also, were dealing, in part at least, with cucumber mosaic.

Lesley and Lesley (23) have reported the occurrence of "wiry" tomato plants resembling in appearance tomatoes affected with fern-leaf mosaic but differing from these by the hereditary nature of the wiry character. The results of their crossing experiments cannot be accepted as positive evidence, however, since insect control was not provided. The fact that the wiry symptoms were not observed to be transmitted in the field is the only evidence presented to establish its noninfectious character.

With the facts at hand, special attention should be given to the work of Kraybill and Eckerson (21). According to these investigators, the juice of tomatoes affected with tomato mosaic can, by means of filtration, be separated into two fractions, one producing mottling symptoms only, while the other causes the formation of fern-leaf symptoms. In regard to their work it should be pointed out in the first place that, judging by their illustrations, their conception of fern-leaf differs from the commonly accepted idea of filiformity. The term fern-leaf is applied by them even to slightly narrowed and malformed laminae, such as frequently occur on tomatoes affected with tobacco mosaic. Only the plant pictured in the center of figure 4 of their paper (21) shows symptoms which suggest the presence of typical filiformity. A careful reading of their paper further reveals the fact that most, if not all, of their inoculations were carried out with inoculum that had been stored for more than one week. Such an aging process will naturally exclude the presence of any cucumber-mosaic virus that might have been present originally. In a more recent publication by Kraybill et al. (22), it is claimed that this filtrate retains its qualities even after being heated for two and a half hours at 126° C. Such a treatment will exclude the presence of cucumber-mosaic virus as well as tobacco-mosaic virus in the inoculum. With the meager data at hand, it is at the present time impossible to form an opinion on this matter which seems to add an entirely new angle to the plant-virus-disease problem.

Of the various types of tomato-mosaic symptoms recognized by Bewley (4) the "tendril-type" is very likely a manifestation of cucumber mosaic. It would be difficult to make any definite statement concerning the other types, especially where illustrations are lacking. It might be mentioned, however, that two types of mosaic on cucumber occur in England, as stated by the same writer. According to the descriptions given by Weber and Ramsey (29), cucumber mosaic on tomatoes may be a disease of importance in Florida. Of the three types distinguished by them, it would seem that the linear type and possibly also the crinkle type are manifestations of cucumber mosaic, while the mottle type resembles tobacco mosaic.

Although not having been able to make a field survey, the writer is inclined to believe that cucumber mosaic on tomatoes is of more frequent occurrence than might be expected at first thought. The occasional appearance of fern-leaf or filiform symptoms cannot be considered as a measure of the distribution of this disease. As has been pointed out in the experimental part of this paper, marked filiformity will result only if the plant is infected at a very early age. Considering the fact that the plants usually are sown in hotbeds, aphid infestations would hardly be expected in the seed bed, and, especially in temperate climates, mass infection thus becomes improbable. The plants used for field planting have often grown beyond the stage where filiform symptoms would result from aphid infection in the field, and the symptoms produced are of a different type and are easily mistaken for tobacco mosaic. Another important factor to be considered in relation to field infection is the migration of the peach aphid. It is possible that where the tomato serves as a secondary host for the peach aphid, the plants will have reached such a size at the time of migration that typical fern-leaf symptoms can no longer be expected. Since other species of aphids have not been studied in connection with the fern-leaf disease, they can at present not be included in the discussion. The more frequent occurrence of fern-leaf under greenhouse conditions can be explained by the increased chance for aphid infestations.

SUMMARY

1. Fern-leaf of tomatoes is chiefly characterized by the presence of filiform leaflets. This symptom has previously been shown to result from virus infection, but its comparatively rare and sporadic natural occurrence, together with the difficulty of reproducing it at will, prompted further investigation.

2. Typical fern-leaf symptoms could not be produced with the ordinary tobacco- or tomato-mosaic virus (*Tobacco virus 1*) under any of the environmental conditions to which the infected host was submitted.

3. Fern-leaf may occasionally be produced by artificial infection of the tomato with the cucumber-mosaic virus (*Cucumber virus 1*), as previously reported by Johnson.

4. Tomato fern-leaf can be produced regularly and at will by infecting young tomato plants with the cucumber-mosaic virus by means of the peach aphid (*Myzus persicae*).

5. The optimum atmospheric temperature for the expression of fern-leaf symptoms lies between 18 and 22° C.; the approximate minimum temperature is 15° C. and the approximate maximum is 25° C.

UNIVERSITY OF WISCONSIN,
MADISON, WISCONSIN.

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EFFECT OF SEED-POTATO TREATMENT ON YIELD AND RHIZOCTONIA IN NORTHEASTERN MAINE FROM 1925 TO 1928[1] [2]

E. S. Schultz,[3] L. O. Gratz,[4] and Reiner Bonde[5]

Introdution

Tests of seed-potato treatments conducted in many potato-growing localities by others have shown that corrosive sublimate is one of the most effective treatments for controlling Rhizoctonia.[6] Although the old standard treatments controlled certain tuber diseases, they frequently failed to increase the yield. In fact, treating occasionally induced significant decreases in yield. Moreover, the additional time and labor involved in treating potatoes greatly contributed to the failure of the majority of the potato growers to treat seed potatoes. This situation encouraged additional investigations on the improvement of seed-treatment materials and methods.

The introduction of hot formaldehyde by Melhus[7] is a distinct improvement in some ways over the older methods. This method greatly reduces the total period of time of treating (though not necessarily the actual labor time per bushel) and is fully as effective as the former standard methods.

The organic mercuries recently developed by the Bayer and du Pont companies[8] have reduced the time of treatment to a minimum and have provided for the treatment of cut as well as whole seed. The yields secured by the use of these newer compounds have compared favorably with those obtained with the old standard treatments. In general, however, they have been reported as not controlling Rhizoctonia as well as corrosive sublimate.

[1] Conducted as a cooperative project between the Bureau of Plant Industry, U. S. Department of Agriculture, the Florida Agricultural Experiment Station, and the Maine Agricultural Experiment Station.

[2] The authors wish to express their gratitude to Dr. W. J. Youden, of the Boyce Thompson Institute for Plant Research, Yonkers, N. Y., for helpful suggestions and criticisms on plans for replicated plots, and to the Bayer and du Pont companies for furnishing various organic-mercury compounds and treatment formulae for their products.

[3] Senior Pathologist, U. S. Department of Agriculture.

[4] Associate Plant Pathologist, Florida Agricultural Experiment Station.

[5] Associate Plant Pathologist, Maine Agricultural Experiment Station.

[6] *Rhizoctonia solani* Kühn, imperfect form of *Corticium vagum* B. & C.

[7] Melhus, I. E. Seed treatment with hot solutions of formaldehyde and mercuric chlorid. Phytopath. 8: 81. 1918.

[8] Now consolidated as the Bayer-Semesan Company, Inc., of New York.

Experience has shown that conflicting results may be obtained from the same treatment in different localities in any one year or in different seasons in any one region.

In view of (1) the new materials and methods, (2) the variation in results according to locality, (3) the importance of Aroostook County (northeastern Maine) as a potato region, and (4) the absence of recent tests of new or standard treatments in Aroostook County, it was thought desirable to conduct such tests in this particular area. This was done from 1925 to 1928, inclusive. A further reason for this work was the hope of determining some of the causes of unexplained variation, especially with reference to controlling Rhizoctonia and increasing the yield.

GENERAL EXPERIMENTAL METHODS

Irish Cobbler tubers uniformly covered with sclerotia of Rhizoctonia were used in the experiments. Clean tubers also were treated with corrosive sublimate to obtain information on soil infestation by Rhizoctonia. In 1925 and 1926 the clean tubers represented a different strain of Irish Cobblers from the diseased lots so that no comparison of yield between the two lots was made in those seasons. In 1927 and 1928, however, clean and diseased tubers were selected from the same strain, thus providing for comparison of yield between the two lots.

The same workman cut the tubers into 1.5-ounce seed pieces for all four seasons, thus providing as uniform seed as possible under representative field conditions. The seed pieces were planted by hand at 14-inch intervals in rows 3 feet apart. Commercial fertilizer, used at the rate of 1500 pounds per acre, was applied in the rows with a planter so that the soil and fertilizer were completely mixed before planting.

During each of the four seasons, the plots were located on apparently uniform Caribou loam on Aroostook Farm, Presque Isle, Maine, where a 3-year rotation with oats, clover, and potatoes is followed.

The potatoes were treated according to the formulae recorded in the tables and were stored in bushel crates in a cool cellar for about two weeks before planting. The tubers treated with hot formaldehyde were covered with burlap for one hour immediately after treating.

Observations were made on stand, relative vigor, seed-piece decay, stem lesions, tuber infection, and yield. Readings on seed-piece decay were taken only in 1927 and 1928. The observations on seed-piece decay and stem lesions were made when the plants were about 4 to 6 inches above the soil; stems showing only slight Rhizoctonia lesions were included in the Rhizoctonia percentages. The percentages of seed-piece decay include partly as well as completely decayed seed pieces. The percentage of tuber infection includes any tubers showing Rhizoctonia sclerotia regardless of

the extent of the infection. This percentage was obtained from representative tuber samples of each replication. In order to obtain reliable data on tuber infection it was necessary to wash the tubers each year at harvest, which began as soon as the foliage had matured.

The yields secured in the 1925 and 1926 experiments were calculated on the basis of total yields, while those obtained in 1927 and 1928 were based on the weights of marketable tubers. Tubers were graded according to the standards of the United States Department of Agriculture. The percentage differences in yield were obtained by comparing the yield of each treated lot with that of the corresponding untreated diseased control. It was found that the percentage differences in yield of marketable tubers, primes, or total tubers were similar.

The formulae $\text{PEM} = \frac{.6745 \times \text{standard deviation}}{\sqrt{\text{no. of items}}}$ and $\text{PED} = \sqrt{a^2 + b^2}$, where a = probable error of the mean of the treated lot and b = probable error of the check with which the treated lot is compared, were used for determining the significance of the differences in yield. Odds as listed by Pearl and Miner[9] were used.

EXPERIMENTAL DATA FOR 1925

Procedure. Twelve treatments as recorded in table 1 were conducted. Each treated diseased lot was planted beside an untreated diseased control and replicated in four 200-foot rows. Every fourth row represented a treated healthy control as an index on soil infestation. The seed pieces were dropped in the open rows and covered immediately after planting. Observations on stand, stem lesions, tuber infection, and yield are recorded in table 1.

Stem lesions. The sprouts from 25 hills per replication, or 100 hills of each lot, were examined for Rhizoctonia lesions to determine their correlation with soil infestation and the disease on the seed pieces and tubers. Clean and infected stems frequently appeared in the same hill where the extent of infection varied from slight lesions to girdling of the shoots. As indicated in table 1, one to 39 per cent of the hills in the treated diseased lots manifested stem lesions, while 65 per cent of the hills in the nontreated controls showed stem infection. Only one per cent of the treated healthy lots showed lesions. This indicates that the percentage of stem lesions was generally correlated with the amount of seed-piece infection and with the control of their infection by treatment.

The lots treated with hot and cold corrosive sublimate showed only 1 per cent each of stem infection and indicated the best control. From the

[9] Pearl, Raymond, and John Rice Miner. A table for estimating the probable significance of statistical constants. Maine Agr. Exp. Sta. Bul. 226: 85–88. 1914.

TABLE 1.—*Results obtained with seed-potato treatments in northeastern Maine in 1925*

Treatment[1]	Percentage of stand	Percentage with stem lesions	Percentage with tuber infection	Calculated yield in bushels per acre		Increase per acre by treating		Odds[2]
				Treated	Not treated	Calculated bushels	Percentage	
Corrosive sublimate 1–3000 and .1% HCl 1½ hr.	97.7	19	10.3	246.8 ± 2.5	223.5 ± 4.5	23.3 ± 5.1	10.4 ± 2.3	519: 1
Uspulun 1–400 1 hr.	98.4	22	16.1	274.0 ± 6.6	249.9 ± 4.4	24.1 ± 8.0	9.7 ± 3.2	22: 1
Uspulun 1–400 50° C. 2 min.	98.8	18	11.9	305.2 ± 5.8	281.5 ± 9.6	23.7 ± 11.2	8.4 ± 4.0	5: 1
Semesan 1–400 1 hr.	98.4	20	11.0	242.5 ± 4.5	223.5 ± 4.5	19.0 ± 6.4	8.5 ± 2.8	22: 1
Bayer-compound 1–400 1 hr.	99.5	39	26.0	268.3 ± 7.7	249.9 ± 4.4	18.4 ± 8.9	7.4 ± 3.6	9: 1
Bayer-compound 1–400 50° C. 2 min.	99.4	28	11.0	299.4 ± 9.4	281.5 ± 9.6	17.9 ± 13.4	6.4 ± 4.8	2: 1
Corrosive sublimate 1–1000 1½ hr.	99.1	1	3.8	278.6 ± 2.6	270.1 ± 3.7	8.5 ± 4.5	3.1 ± 1.7	4: 1
Corrosive sublimate 1–500 50° C. 2 min.	98.6	1	2.3	275.5 ± 3.9	270.1 ± 3.7	5.4 ± 5.3	2.0 ± 2.0	1: 1
Semesan 13U dust 3 oz. per bu.	99.4	8	7.6	286.4 ± 5.4	282.2 ± 5.8	4.2 ± 8.0	1.5 ± 2.8	0
Formaldehyde 1–120 50° C. 2 min.	97.2	14	6.4	296.7 ± 1.3	294.9 ± 2.6	1.8 ± 2.9	0.6 ± 1.0	0
Bayer dust (tubers presprinkled) 4 oz. per bu.	98.6	7	7.8	283.1 ± 4.0	282.2 ± 5.8	0.9 ± 7.1	0.3 ± 2.5	0
Formaldehyde 1–240 2 hrs.	97.5	15	6.3	287.1 ± 2.4	294.9 ± 2.6	−7.8 ± 3.5	−2.6 ± 1.2	6: 1
Check, diseased, not treated	96.4	65	22.3					
Check, clean, corrosive sublimate 1–1000 1½ hr.	96.0	1	2.0					

[1] Whole tubers treated in all lots.

[2] Significance is shown by odds of over 22 to 1.

percentage of stem infection, especially in the untreated lots, one might have expected considerable unevenness in stand later. However, at blossoming time the general appearance of the tops in the treated and untreated lots was the same.

Tuber infection. On September 17, shortly after the death of the tops, the plots were harvested and one-bushel samples per replication, selected from representative sections of the plot, were reserved for observations on tuber infection. Each sample of approximately 200 tubers was examined for Rhizoctonia sclerotia.

The data on tuber infection recorded in table 1 disclose the fact that corrosive sublimate gave the best control. With the exception of the Bayer-compound-treated lot, showing slightly more tuber infection than the diseased control, the treated lots manifested less infection than the diseased control. A close correlation was found between stem infection and tuber infection. In general, smoother, cleaner, and less deformed tubers appeared in the treated than in the nontreated lots, although the relative percentage of badly infected tubers was so small that the appearance of the entire stock was not marred.

Yield. Significant increases in yield were obtained from the lots treated with acidulated corrosive sublimate, Uspulun and Semesan. With the exception of the lot treated with cold formaldehyde, which gave a slight decrease in yield, the other treated lots showed slight increases in yield over the diseased control. It is interesting to note that the highest increases in yield were obtained from the treated lots possessing relatively high percentages of stem and tuber infection, which suggests that Rhizoctonia infection was not the only determining factor but that possibly injurious effects from certain treatments may have reduced yield more than did the effects from Rhizoctonia.

EXPERIMENTAL DATA FOR 1926

Procedure. As recorded in table 2, eighteen treatments were compared in 1926. Three replications of 25 hills each were conducted for each treatment. Every fifth, sixth, and seventh row represented a clean nontreated, a clean treated, and a diseased nontreated control, respectively.

In view of the small number of replications, individual hill weights of all the lots were taken to secure adequate comparisons between the diseased treated lots and the nontreated controls. Since the clean treated and nontreated lots represented a different strain of Irish Cobblers from the diseased lots, comparisons of yield between them were not made.

Formulae and results of the treatments are recorded in table 2.

Stem lesions. As shown in table 2, all treatments reduced the number of stem lesions. The treated diseased lots manifested 0 to 33 per cent of

TABLE 2.—*Results obtained with seed-potato treatments in northeastern Maine in 1926*

Treatment	Tubers when treated[1]	Percentage of stand	Relative vigor	Percentage with stem lesions	Percentage with tuber infection	Calculated yield in bushels per acre		Increase per acre by treating		
						Treated	Not treated	Calculated bushels	Percentage	Odds[2]
Semesan Bel 1–20 dip	C	96.0	91.7	1.7	2.0	248.3 ± 7.8	205.4 ± 7.8	42.9 ± 11.0	20.9 ± 5.4	116:1
Corrosive sublimate 1–500 52° C. 2 min.	W	96.0	87.3	5.0	3.0	261.3 ± 9.1	218.4 ± 7.8	42.9 ± 12.0	19.6 ± 5.5	64:1
12 Bel 1–10 dip	C	90.7	86.7	0.0	7.4	241.8 ± 9.1	205.4 ± 7.8	36.4 ± 12.0	17.7 ± 5.8	22:1
Formaldehyde 1–120 52° C. 2 min.	W	96.0	83.3	13.3	12.6	240.5 ± 9.1	205.4 ± 7.8	35.1 ± 12.0	17.1 ± 5.8	19:1
Semesan Bel dust 3 oz. per bu.	C	97.3	91.7	20.0	29.3	236.6 ± 6.5	205.4 ± 7.8	31.2 ± 10.1	15.2 ± 4.9	26:1
Semesan Bel 1–10 dip	W	100.0	88.6	33.3	47.3	230.1 ± 5.2	198.9 ± 6.5	31.2 ± 8.3	15.7 ± 4.2	95:1
Bayer Dust II–6 3 oz. per bu.	C	100.0	95.7	15.0	27.0	226.2 ± 5.2	198.9 ± 6.5	27.3 ± 8.3	13.7 ± 4.2	37:1
Uspulun 1–400 1 hr.	C	94.7	90.3	20.0	5.2	224.9 ± 7.8	198.9 ± 6.5	26.0 ± 10.1	13.1 ± 5.1	11:1
Formaldehyde 1–240 2 hr.	W	100.0	94.0	10.0	10.0	247.0 ± 5.2	218.4 ± 7.8	28.6 ± 9.4	13.1 ± 4.3	26:1
Semesan 1–400 1 hr.	C	98.7	82.7	13.3	13.4	244.4 ± 6.5	223.6 ± 9.1	20.8 ± 11.2	9.3 ± 5.0	4:1
Bayer-compound 1–400 1 hr.	C	89.3	88.3	15.0	22.6	214.5 ± 7.8	198.9 ± 6.5	15.6 ± 10.1	7.8 ± 5.1	2:1
37 Bel dust 3 oz. per bu.	C	97.3	85.0	3.3	10.3	236.6 ± 6.5	223.6 ± 9.1	13.0 ± 11.2	5.8 ± 5.0	1:1
12 Bel dust 3 oz. per bu.	C	98.7	92.3	13.3	24.3	244.4 ± 5.2	232.8 ± 9.1	11.6 ± 10.5	5.0 ± 4.5	1:1
Bayer Special 90 1–20 dip	C	98.7	92.7	1.7	14.6	247.0 ± 6.5	241.8 ± 6.5	5.2 ± 9.2	2.2 ± 3.8	0
Bayer Special 89 1–20 dip	C	94.7	95.0	23.3	27.9	235.3 ± 6.5	241.8 ± 6.5	−6.5 ± 9.2	−2.7 ± 3.8	0
Corrosive sublimate 1–1000 1½ hr.	W	84.0	78.7	5.0	2.0	210.6 ± 9.1	218.4 ± 7.8	−7.8 ± 12.0	−3.6 ± 5.5	0
37 Bel 1–10 dip	C	88.0	71.0	1.6	0.0	211.9 ± 9.1	223.6 ± 9.1	−11.7 ± 12.8	−5.2 ± 5.7	1:1
Semesan Bel dust 3 oz. per bu.	W	97.3	90.0	25.0	36.9	222.3 ± 6.5	241.8 ± 6.5	−19.5 ± 9.2	−8.1 ± 3.8	5:1
Check, diseased, not treated		96.3	79.9	49.3	39.5	See next column				
Check, clean, not treated		98.7	97.5	1.0	4.9					
Check, clean, corrosive sublimate 1–1000 1½ hr.	W	99.0	96.8	1.3	4.0					

[1] C = cut seed pieces treated; W = whole tubers treated.
[2] Significance is shown by odds of over 22 to 1.

stem infection, while the diseased control showed 49 per cent and the treated clean but one per cent of infection, thus indicating a close association of seed-piece infection with stem lesions.

The most effective control was found in the lots treated with 12 Bel, 37 Bel, Semesan Bel 1–20, Bayer Special 90, 37 Bel dust, and cold and hot corrosive sublimate showing 0, 1.6, 1.7, 1.7, 3.3, 5, and 5 per cent of stem infection, respectively. Different concentrations and forms of the same products gave inconsistent results; the 37 Bel dip and dust treatments were about equally effective in controlling stem infection, while Semesan Bel dip 1–20 on cut seed appeared much more effective than Semesan Bel dip 1–10 on whole tubers or dust on cut seed. The results indicate that the liquid treatments controlled stem lesions better than the dusts.

Tuber infection. As in 1925, observations on tuber infection disclosed a close correlation between stem lesions and tuber infection. 37 Bel dip gave perfect control, while the lots treated with cold corrosive sublimate and Semesan Bel dip 1–20 gave 2 per cent of infected tubers. The non-treated clean and diseased controls produced 4.9 and 39.5 per cent of tuber infection, respectively. The lot treated with Semesan Bel dip 1–10 manifested 47.3 per cent of infected tubers and was the only treated lot which showed more disease than the diseased control. The extent of Rhizoctonia infection on the tubers was similar to that in 1925 and did not affect materially the appearance of the entire stock.

Yield. Significant increases in yield were obtained from the lots treated with Semesan Bel dip on whole and cut tubers, 12 Bel dip, Bayer Dust 11–6, Semesan Bel dust on cut tubers, hot corrosive sublimate, and hot and cold formaldehyde. The lots treated with cold corrosive sublimate, 37 Bel dip, Semesan Bel dust, and Bayer Special 89 dip yielded slightly less than the diseased control. It is noteworthy that, as in 1925, certain treatments, giving very good control of Rhizoctonia, did not increase the yield. This suggests that possible injury from treatment may be more detrimental to the plants than Rhizoctonia. The hot corrosive-sublimate lot produced next to the highest increase in yield, while the one treated with cold corrosive sublimate slightly underyielded the control, indicating that the same material differently applied may vary greatly in its effects in the same season. Cold formaldehyde effected a significant increase in yield in 1926, while in 1925 this treatment produced a slight decrease in yield, showing that the effects of the same material may vary widely in different seasons in the same locality. That low vigor is not invariably associated with low yield is shown by the high vigor but low yields from the lot treated with Bayer Special 89 dip.

Although the yields of the healthy lots were not compared with the diseased lots on account of difference in origin of the two, it is noteworthy

that the diseased lot treated with the cold corrosive sublimate manifested a relative vigor of 78.7, while the clean lot given the same treatment showed a relative vigor of 96.8. This indicates that a different reaction may be obtained from different lots of the same variety of seed potatoes treated with the same treatment in the same season and locality.

EXPERIMENTAL DATA FOR 1927

Procedure. The clean and diseased tubers were obtained from the same commercial stock of Irish Cobblers. The treated lots and nontreated controls were planted in plots arranged according to the chessboard plan (Table 5), a modification of the magic-square system. This plan provides for better distribution of the different lots from the standpoint of competition and soil variations than do the systems followed in 1925 and 1926. Moreover this plan provides for more satisfactory biometrical measurements with more replications, but with fewer plants per replication, than does that of 1925. Although ten 25-hill plots per treatment were made, yields were calculated for nine replications in view of considerable soil variation in one replication.

Observations on stem lesions and seed-piece decay were made on 52 hills per treatment which were planted in a plot adjoining the one for yields and were examined when the plants were about 4 to 6 inches above the soil.

The formulae and results of the treatments are recorded in table 3.

Seed-piece decay. The treatments apparently inhibited seed-piece decay. The nontreated diseased control showed decay in 100 per cent of the seed pieces in contrast with four of the treated diseased lots which remained free of decay. The nontreated clean control developed 33 per cent of decay, while the corrosive-sublimate-treated lot showed none. However, the clean lot treated with 2B dip had 15 per cent more decay than the nontreated clean control, thus suggesting that this might have caused seed-piece injury and subsequent decay. The diseased nontreated control, showing 66 per cent more decay than the clean nontreated control, seems to indicate that Rhizoctonia on the seed pieces favors seed-piece decay. However, further work on this phase of seed-potato treatment is necessary before all factors influencing seed-piece decay are known. Contrary to expectations, seed-piece decay was controlled as well by treating whole tubers as by treating cut tubers.

Stem lesions. Two clean treated lots and the clean nontreated control did not develop stem infection, while the diseased treated lots developed from 2 to 40 per cent of stem lesions. Corrosive sublimate and cold formaldehyde gave the best control, with lesions on but 2 per cent of the plants. It is interesting to note that the diseased check with 8 per cent

TABLE 3.—*Results obtained with seed-potato treatments in northeastern Maine in 1927*

Treatment	Tubers when treated[1]	Percentage stand	Relative vigor	Percentage with seed-piece decay	Percentage with stem lesions	Percentage with tuber infection	Marketable tubers			
							Yield per acre in bushels	Increase in yield over diseased untreated check		
								Bushels per acre	Percentage	Odds[2]
Corrosive sublimate 1–1000 1½ hr.	W	98.8	88.5	0.0	2.0	14	418.3 ± 5.9	78.5 ± 8.1	23.1 ± 2.4	M[3]: 1
Formaldehyde 1–240 2 hr.	W	96.4	82.4	0.0	2.0	26	411.5 ± 3.9	71.7 ± 6.7	21.1 ± 2.0	M: 1
Formaldehyde 1–120 52° C. 3 min.	W	93.2	81.6	0.0	26.0	25	403.9 ± 6.8	64.1 ± 8.8	18.9 ± 2.6	434782: 1
Semesan Bel 1–10 dip	W	97.2	86.6	24.0	20.0	33	399.3 ± 8.4	59.5 ± 10.0	17.5 ± 2.9	19230: 1
Semesan Bel 1–10 dip	C	96.8	87.2	27.0	40.0	43	410.0 ± 4.3	70.2 ± 7.0	20.7 ± 2.1	M: 1
2 B 1–20 dip	C	94.0	81.8	24.0	16.0	42	377.4 ± 4.8	37.6 ± 7.3	11.1 ± 2.2	1350: 1
2 B 1–30 dip	C	91.6	76.4	62.0	22.0	39	356.7 ± 6.1	16.9 ± 8.3	5.0 ± 2.4	4: 1
12 Bel 1–20 dip	C	98.8	92.0	2.0	36.0	38	398.8 ± 4.0	59.0 ± 6.8	17.4 ± 2.0	M: 1
21 Bel 1–20 dip	C	98.4	88.0	2.0	12.0	34	394.2 ± 4.6	54.4 ± 7.2	16.0 ± 2.1	M: 1
37 Bel 1–20 dip	C	98.8	87.0	0.0	34.0	41	402.9 ± 5.2	63.1 ± 7.6	18.6 ± 2.2	M: 1
62 B 1–20 dip	C	99.6	89.5	0.0	17.0	30	402.7 ± 3.7	62.9 ± 6.6	18.5 ± 1.9	M: 1
Dipdust 1–20 dip	C	97.6	91.4	14.0	22.0	41	407.0 ± 5.1	67.2 ± 7.5	19.8 ± 2.2	M: 1
Dipdust 1–20 dip	W	98.0	89.6	2.0	29.0	36	402.4 ± 9.4	62.6 ± 10.9	18.4 ± 3.2	19230: 1
Bayer Special 181 1–40 dip	C	98.0	88.7	14.0	32.0	35	393.6 ± 6.5	53.8 ± 8.5	15.9 ± 2.5	19230: 1
Bayer Special 181 1–40 dip	W	99.2	86.4	36.0	36.0	37	386.6 ± 5.5	46.8 ± 7.8	13.8 ± 2.3	19230: 1
Diseased, check, untreated		89.2	71.8	100.0	8.0	27	339.8 ± 5.5			
Clean, check, untreated		98.4	89.0	33.0	0.0	18	398.9 ± 6.1	59.1 ± 8.2	17.4 ± 2.4	434782: 1
Clean, corrosive sublimate 1–1000 1½ hr.	W	98.4	85.4	0.0	0.0	15	415.7 ± 4.9	75.9 ± 7.4	22.3 ± 2.2	M: 1
Clean 2 B 1–20 dip	C	97.6	86.0	48.0	0.0	21	389.2 ± 5.3	49.4 ± 7.6	14.5 ± 2.2	19230: 1
Clean, Dipdust 1–20 dip	C	99.2	93.7	6.0	10.0	15	415.3 ± 6.1	75.5 ± 8.2	22.2 ± 2.4	M: 1

[1] W = whole tubers treated; C = tubers treated after cutting.
[2] Significance is shown by odds of over 22 to 1.
[3] M = a million or more.

stem lesions showed considerably less infection than most of the treated diseased lots, which probably indicates that the extensive seed-piece decay in this lot might have inhibited Rhizoctonia from infecting the stems. Only a trace of Rhizoctonia hills with aerial tubers and of black-leg plants appeared in the plots.

Tuber infection. The percentage of infected tubers in the different treated diseased lots ranged from 14 to 43. Corrosive sublimate gave the best control. It is noteworthy that the diseased control, with only 27 per cent tuber infection, showed less Rhizoctonia on the tubers than most of the treated lots. This was contrary to the results of tuber infection obtained from the diseased control in 1925 and 1926, when, with one exception, it gave the highest percentage of infected tubers. Whether the extensive seed-piece decay in the diseased control or variations in soil infestation, as suggested by relatively high tuber infection in the clean controls, influenced the results was not determined. With a few exceptions, probably induced by variations in soil infestation, a rather close correlation appears between stem lesions and tuber infection.

Yield. As recorded in table 3, significant increases in yield were obtained with all treatments except duPont 2B dip 1–30 which effected only a slight increase over the diseased control. It is interesting to note that the yield from the corrosive-sublimate treatment was from 1 to 18 per cent greater than that from other treatments. However, only slightly lower yields resulted from treatments with Semesan Bel and Dipdust on cut seed and with cold formaldehyde than from corrosive sublimate. DuPont 2B apparently was injurious.

The greater number of treated lots showing increases in yield than in 1925 and 1926 may be due to more extensive seed-piece decay as well as more Rhizoctonia infection in 1927 than during the two previous seasons. These results suggest that the control of seed-piece decay by treating was one of the primary factors contributing towards significant increases in yield. A relative vigor below 80 was apparently associated with the lowest yields, but the highest relative vigor was not correlated with the highest yields.

EXPERIMENTAL DATA FOR 1928

Procedure. A similar series of treatments with the same plot arrangement as in 1927 was conducted in 1928. The Bayer products, Dipdust and Bayer Special 181, were the same as those used in 1927, so that the results of these materials and of the old standard treatments can be compared for the two seasons. Certain modifications of the du Pont products, Semesan Bel and 76 Bel, prevent similar comparisons with them. Ten 26-hill replications per treatment were made. The formulae and results of the treatments are recorded in table 4.

TABLE 4.—*Results obtained with seed-potato treatments in northeastern Maine in 1928*

Treatment	Tubers when treated[1]	Percentage of stand	Relative vigor	Percentage with seed piece decay	Percentage with stem lesions	Percentage with tuber infection	Marketable tubers			
							Yield per acre in bushels	Increase over diseased untreated check		
								Bushels	Percentage	Odds[2]
Clean, Dipdust 1–20 dip	W	98.8	86	6	6	28	374.2 ± 7.1	74.2 ± 8.8	24.7 ± 2.9	M[3]: 1
Clean, Dipdust 1–20 dip	C	98.1	88	40	14	42	369.0 ± 6.6	69.0 ± 8.4	23.0 ± 2.8	M: 1
Clean, corrosive sublimate 1–1000 1½ hr.	W	98.1	87	8	2	27	368.2 ± 7.0	68.2 ± 8.7	22.7 ± 2.9	M: 1
Clean, Semesan Bel 1–20 dip	C	92.2	89	34	37	39	366.2 ± 6.6	66.2 ± 8.4	22.1 ± 2.9	M: 1
76 Bel 1–40 dip	W	98.9	81	8	4	25	362.2 ± 5.4	62.2 ± 7.6	20.8 ± 2.5	M: 1
Clean, check, not treated		99.2	83	10	14	35	361.8 ± 5.2	61.8 ± 7.4	20.6 ± 2.5	M: 1
Formaldehyde 1–240 2 hr.	W	99.6	84	14	14	38	359.0 ± 7.0	59.0 ± 8.7	19.7 ± 2.9	434782: 1
Corrosive sublimate 1–1000 1½ hr.	W	96.5	80	2	10	27	358.6 ± 5.7	58.6 ± 7.7	19.5 ± 2.6	M: 1
Clean, Semesan Bel 1–20 dip	W	100.0	88	4	30	29	358.2 ± 7.2	58.2 ± 8.9	19.4 ± 3.0	M: 1
Dipdust 1–20 dip	C	98.1	81	16	38	70	351.0 ± 5.5	51.0 ± 7.6	17.0 ± 2.5	434782: 1
77 Bel 1–20 dip	W	98.8	78	2	35	60	347.0 ± 5.3	47.0 ± 7.5	15.7 ± 2.5	19230: 1
Dipdust 1–20 dip	W	99.2	76	14	45	67	340.3 ± 5.4	40.3 ± 7.5	13.4 ± 2.5	1350: 1
Bayer Special 190 1–20 dip	W	98.8	73	12	37	64	339.9 ± 4.2	39.9 ± 6.7	13.3 ± 2.2	19230: 1
76 Bel 1–40 dip	C	98.8	72	2	8	30	335.1 ± 7.7	35.1 ± 9.3	11.7 ± 3.1	95: 1
Bayer Special 181 1–40 dip	W	98.1	69	4	26	68	329.5 ± 7.0	29.5 ± 8.7	9.8 ± 2.9	45: 1
Semesan Bel 1–20 dip	C	95.0	74	60	33	61	325.9 ± 5.7	25.9 ± 7.7	8.6 ± 2.6	32: 1
Formaldehyde 1–120 52° C. 3 min.	W	98.5	60	4	16	36	317.9 ± 6.8	17.9 ± 8.6	6.0 ± 3.0	4.6: 1
Semesan Bel 1–20 dip	W	99.6	63	14	56	88	317.5 ± 5.1	17.5 ± 7.3	5.8 ± 2.4	8.5: 1
Diseased, water, dip	W	95.6	65	48	62	66	310.3 ± 3.3	10.3 ± 6.1	3.4 ± 2.0	3: 1
Diseased, check, not treated		96.5	57	38	79	83	300.0 ± 5.2			

[1] W = whole; C = cut.
[2] Significance is shown by odds of over 22 to 1.
[3] M = a million or more.

Seed-piece decay. Seed-piece decay ranging from 2 to 60 per cent appeared in the different lots. The lots treated with 76 and 77 Bel dip and with corrosive sublimate each developed only 2 per cent of decay, while the nontreated diseased and water-dipped diseased controls showed 38 and 48 per cent of decay, respectively. Cut seed treated with Improved Semesan Bel developed 60 per cent decay, suggesting injury as well as ineffective control of organisms responsible for decay. The highest percentage of seed-piece decay appeared on treated cut seed and on the diseased controls, indicating possible treatment injury as well as injury from organisms harbored in the soil or on the tuber.

Stem lesions. Stem infection ranged from 4 to 56 per cent for the treatments, while the highest infection, 79 per cent, appeared on the diseased control. The best control was obtained with 76 Bel which apparently was slightly more effective than corrosive sublimate. The total injury from lesions was most severe in the lots showing the highest percentage of infected stems. As in previous seasons, stem infection was closely correlated with infection of seed pieces, although the relatively high stem infection in the clean controls indicates either some undetected seed-piece infection or soil infestation.

Each of 12 treated lots developed 1 per cent or less of black-leg hills, while the remaining six treated lots showed from 1 to 3 per cent black leg, the highest percentage appearing in the lot treated with hot formaldehyde. No black leg occurred in the diseased control. Although present, black leg was not abundant enough to lead to definite conclusions.

Tuber infection. The diseased lots showing the lowest tuber infection, 25 and 27 per cent, were treated with 76 Bel and corrosive sublimate, respectively. The highest percentage, 88, of infected tubers appeared in the lot treated with Improved Semesan Bel, which was the only one showing more infection than the diseased control. The relatively high percentage of infected tubers in the clean treated and clean control lots indicates some infection from the seed pieces or from the soil. Some correlation appears between stem lesions and tuber infection.

Yield. Significant increases in yield were obtained from all the treatments, with the exception of Improved Semesan Bel used on whole tubers, which yielded only slightly more than the diseased control. The highest increases in yield in the diseased lots were obtained with 76 Bel, cold formaldehyde, and corrosive sublimate. Hot formaldehyde gave fair control of Rhizoctonia infection but increased the yield only 6 per cent. This is barely significant. Possibly this treatment was injurious to the seed pieces and thus inhibited the yield as much as did injury from Rhizoctonia. Clean seed treated with Dipdust, corrosive sublimate, and Semesan Bel dip produced slightly higher yields than the highest yielding, treated, dis-

eased lots and the clean control. The lowest yielding lots were also associated with the lowest relative vigor.

As in previous seasons, the greatest increases in yield were not invariably obtained from the lots showing low infection with Rhizoctonia, a fact which suggests that possible treatment injury may reduce yield more than does Rhizoctonia infection.

DISCUSSION AND CONCLUSIONS

Recent results from investigations outside of Maine.—The writers have made a survey of results reported from recent seed-potato-treatment experiments, especially with reference to the effects upon Rhizoctonia and yield. In view of the nature of the problem and of the results, it seems desirable to present here only the conclusions derived from this survey.

The results of the various recent investigations on potato treatment for Rhizoctonia show that corrosive sublimate is one of the most effective treatments for controlling this disease. However, in some cases corrosive sublimate has not been significantly more effective in killing Rhizoctonia sclerotia than formaldehyde or certain of the organic-mercury products.

The recent evidence on yield obtained with seed-potato treatments by investigators in different localities indicates that significant increases in yield resulted in some localities, while slight to significant decreases in yield appeared in the same season in other localities. Moreover, in the same locality increases in yield resulted in one season, while in another decreases in yield appeared in connection with the same treatment. Comparative seed-potato treatments with corrosive sublimate, hot formaldehyde, and organic-mercury fungicides conducted in the principal potato-producing States indicated that certain organic-mercury preparations gave more uniform results on yield than either corrosive sublimate or hot formaldehyde.

The evidence that certain treatments giving the best control of Rhizoctonia failed sometimes to increase the yield indicates that injurious effects on the tubers from treating may inhibit yield more than Rhizoctonia.

This brief summary from a review of literature shows that the results obtained elsewhere lead to the same general conclusions as may now be drawn from the results in Maine.

Results in Maine. Treating Rhizoctonia-infected potatoes with corrosive sublimate, formaldehyde, and certain organic-mercury fungicides effectively inhibited Rhizoctonia. However, the percentage of badly infected tuber progeny from the nontreated diseased controls frequently was so low that the appearance of the entire lot was not greatly affected. Under such conditions, it is apparent that the advisability of treating seed potatoes could be questioned unless significant increases in yield could be shown. From the results on control and yield obtained in 1925 one might

have doubted the advisability of seed-potato treatment, particularly of tubers relatively free from Rhizoctonia sclerotia.

However, the results obtained from the experiments in 1926 to 1928 show that under other conditions certain treatments effected significant increases in yield and, with a few exceptions, increased the percentage of clean tubers.

Nontreated clean tubers, which did not manifest Rhizoctonia sclerotia, frequently produced cleaner tuber progeny and greater increases in yield than treated diseased tubers, which were uniformly covered with sclerotia. These results indicate that seed-piece-infection was correlated with infection of progeny and with yield. A similar correlation appeared between Rhizoctonia infection of seed pieces and of stems in the absence of soil infestation or in soils apparently slightly infested with Rhizoctonia.

The evidence that certain treatments inhibited seed-piece decay, which apparently affected the yield in 1927, emphasizes the importance of observations on the condition of the seed piece in the soil and on the vigor of the plants. It is probable that Rhizoctonia at times may have been wrongly regarded as the primary cause of reduced yields, unless this disease should be related in some manner to conditions favoring seed-piece decay. It is interesting to note that in 1927 all the seed pieces in the nontreated Rhizoctonia control manifested different stages of decay involving in severe cases the entire seed piece when the plants were about 6 inches above ground, while no decay occurred in several of the treated lots. The greater number of treatments showing significant increase in yield in 1927 than during the two previous seasons apparently indicates that seed-piece decay may have been one of the contributing factors.

Results on control of Rhizoctonia and on yield obtained from 1925 to 1928 with some organic mercuries and with corrosive sublimate and formaldehyde are represented in figure 1. The corrosive sublimate and formaldehyde treatments were applied to whole tubers. In 1925 and 1928 the organic-mercury treatments represented in figure 1 were applied to whole tubers, while, in 1926 and 1927, these treatments were used on cut tubers. Since the differences between treated cut and treated whole tubers were not invariably significant regarding yield or control, these factors do not materially affect the comparison of the results. Certain modifications of the organic-mercury preparations made by the manufacturers during the four seasons prevent adequate season-to-season comparisons of these results. However, the effectiveness of these products can be compared with that of corrosive sublimate and formaldehyde during the same season.

Although our experience with seed-potato treatments conducted on the same farm during four seasons shows that Rhizoctonia can be inhibited and that the yields can be maintained as well as increased, the results ob-

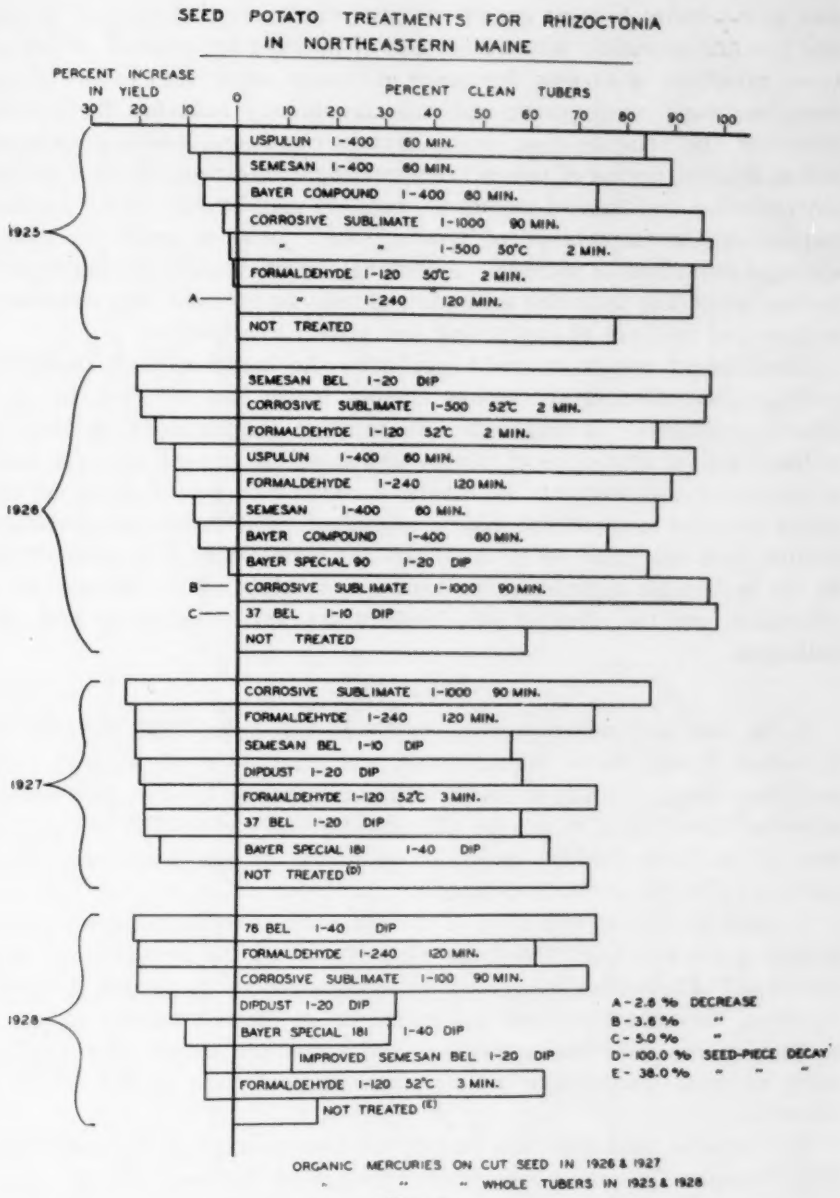
SEED POTATO TREATMENTS FOR RHIZOCTONIA
IN NORTHEASTERN MAINE
PERCENT INCREASE IN YIELD
30 20 10 0
PERCENT CLEAN TUBERS
10 20 30 40 50 60 70 80 90 100
1925
USPULUN 1-400 60 MIN.
SEMESAN 1-400 60 MIN.
BAYER COMPOUND 1-400 60 MIN.
CORROSIVE SUBLIMATE 1-1000 90 MIN.
" " 1-500 50°C 2 MIN.
FORMALDEHYDE 1-120 50°C 2 MIN.
A " 1-240 120 MIN.
NOT TREATED
1926
SEMESAN BEL 1-20 DIP
CORROSIVE SUBLIMATE 1-500 52°C 2 MIN.
FORMALDEHYDE 1-120 52°C 2 MIN.
USPULUN 1-400 60 MIN.
FORMALDEHYDE 1-240 120 MIN.
SEMESAN 1-400 60 MIN.
BAYER COMPOUND 1-400 60 MIN.
BAYER SPECIAL 90 1-20 DIP
B CORROSIVE SUBLIMATE 1-1000 90 MIN.
C 37 BEL 1-10 DIP
NOT TREATED
1927
CORROSIVE SUBLIMATE 1-1000 90 MIN.
FORMALDEHYDE 1-240 120 MIN.
SEMESAN BEL 1-10 DIP
DIPDUST 1-20 DIP
FORMALDEHYDE 1-120 52°C 3 MIN.
37 BEL 1-20 DIP
BAYER SPECIAL 181 1-40 DIP
NOT TREATED (D)
1928
76 BEL 1-40 DIP
FORMALDEHYDE 1-240 120 MIN.
CORROSIVE SUBLIMATE 1-100 90 MIN.
DIPDUST 1-20 DIP
BAYER SPECIAL 181 1-40 DIP
IMPROVED SEMESAN BEL 1-20 DIP
FORMALDEHYDE 1-120 52°C 3 MIN.
NOT TREATED (E)
A - 2.8 % DECREASE
B - 3.6 % "
C - 5.0 % "
D - 100.0 % SEED-PIECE DECAY
E - 38.0 % " " "
ORGANIC MERCURIES ON CUT SEED IN 1926 & 1927
" " " WHOLE TUBERS IN 1925 & 1928

FIG. 1

tained here must not be regarded as criteria of what may occur under different conditions. Treating small lots of potatoes, storing them in crates favorable to drying after treating, and planting the seed pieces by hand

may be conducive to more nearly optimum conditions than prevail in general practice, especially where large lots of potatoes are treated. Furthermore, variations in variety, dormancy of tubers, nature and extent of diseases, moisture, temperature, and soil may greatly influence the results. Moreover, the evidence that, under certain conditions, treating sprouted tubers, delayed drying of tubers after treating, and exceeding the optimum concentration and time of treatment, potatoes may be injured by treating emphasizes the importance of treating seed potatoes under as nearly optimum conditions as possible. Additional investigations covering various factors, which may influence the results of treating potatoes, may contribute to improved methods of conducting seed-potato treatments.

Inconsistent results on yield emphasize the importance of additional investigations relating to various factors which are involved in seed-potato treatments. It will suffice to mention improvement in treating methods and in conditions of storing and handling treated potatoes, stage of dormancy and maturity of tubers, variations in susceptibility of different varieties to treatment injury, modifications of disinfecting products making them less injurious to the tubers but maintaining their toxic effects on the pathogenic organisms, the nature and extent of the diseases to be controlled, and the effect of soil, temperature, and moisture on host and pathogene.

SUMMARY

1. In the seed-potato treatments conducted from 1925 to 1928 on Aroostook Farm, Maine, consideration was given to replication of plots, seed-piece decay, stand (percentage of plants emerging), vigor, stem lesions, sclerotial infection of tubers by Rhizoctonia, and yield. The treated lots were of the Irish Cobbler variety, were mostly of one commercial stock, and were planted in Caribou loam.

2. Seed treatment with most of the materials reduced seed-piece decay, improved the stand, increased the vigor, inhibited the formation of stem lesions and of tuber-borne sclerotia by Rhizoctonia, and increased the yield. However, the same treatment has varied in its effects from one season to another, giving sometimes significant and sometimes nonsignificant differences or even undesirable results such as seed-piece injury or yield reduction.

3. Corrosive sublimate was one of the best treatments for controlling Rhizoctonia and in two seasons effected the highest increase in yield. However, the increased yields obtained with corrosive sublimate were not always significantly greater than those obtained with formaldehyde and with certain organic-mercury compounds. Hot corrosive sublimate gave as effective control of Rhizoctonia as cold corrosive sublimate. Hot formalde-

TABLE 5.—*Arrangement of seed-potato treatment plots in 1927*

J	Buffer row	15	13	17	11	19	9	20	7	18	5	16	3	14	1	12	2	10	4	8	6	Buffer row	20	10	1	11
I		3	1	5	2	7	4	9	6	11	8	13	10	15	12	17	14	19	10	20	18		19	9	2	12
H		14	16	12	18	10	20	8	19	6	17	4	15	2	13	1	11	3	9	5	7		18	8	3	13
G		9	7	11	5	13	3	15	1	17	2	19	4	20	6	18	8	16	10	14	12		17	7	4	14
F		16	18	14	20	12	19	10	17	8	15	6	13	4	11	2	9	1	7	3	5		16	6	5	15
E		2	4	1	6	3	8	5	10	7	12	9	14	11	16	13	18	15	20	17	19		15	5	6	16
D		13	11	15	9	17	7	19	5	20	3	18	1	16	2	14	4	12	6	10	8		14	4	7	17
C		10	12	8	14	6	16	4	18	2	20	1	19	3	17	5	15	7	13	9	11		13	3	8	18
B		17	15	19	13	20	11	18	9	16	7	14	5	12	3	10	1	8	2	6	4		12	2	9	19
A[1]		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		11	1	10	20
																							K	K	L	L

[1] A to L represent replications of which A to J were used for yields and K and L for observations on stem lesions and seed-piece decay.

The numbers represent the different treatments.

hyde controlled Rhizoctonia as well as cold formaldehyde, but was less effective than corrosive sublimate.

4. Among the organic-mercury fungicides 76 Bel dip, used only in 1928, was as effective for Rhizoctonia control and for increase in yield as corrosive sublimate. Although Dipdust (1–20) used in 1927 and 1928 gave consistent increases in yield, it did not inhibit Rhizoctonia as well as corrosive sublimate and formaldehyde. Semesan Bel (1–10) used in 1926 and 1927 gave about the same results as Dipdust (1–20). Improved Semesan Bel (1–20) used in 1928 apparently was less effective than Semesan Bel (1–10).

5. Seed treatment was most effective on seed tubers infected with Rhizoctonia. Beneficial results were also secured in some cases by seed treatment of apparently disease-free tubers.

6. Seed-piece decay was inhibited as well by treating whole tubers as by treating cut seed. Seed-piece decay sometimes reduced the stand, vigor, amount of Rhizoctonia infection of stems and tubers, and yield.

7. Tuber infection by Rhizoctonia sclerotia was not necessarily abundant enough to detract from the appearance of the crop even when grown from nontreated infected seed.

8. As indicated above, the yield was influenced by various conditions of the test. It was increased most by Rhizoctonia control in 1928; but, in 1927, was increased most by control of seed-piece decay.

9. Recent tests conducted outside of Maine and those reported here, agree in respect to the variable effect of seasonal or climatic factors, and that the same treatment may vary in results with the locality and type of soil.

10. The development of disinfecting products simple in application, noninjurious to the seed potatoes, and effective in disease control appears essential for insuring the widest application of seed-potato treatments. Noninjurious instantaneous dip treatments perfected so that they will control Rhizoctonia and similar tuber-borne maladies more effectively than the present products seem to offer possible prospects for improving seed-potato treatment.

TWO PHYSIOLOGIC FORMS OF *USTILAGO STRIAEFORMIS* (WESTD.) NIESSL

W. H. DAVIS

Ustilago striaeformis is a smut organism which commonly parasitizes many of our common grasses. Mycologists and pathologists have based the classification of this organism on the following morphological characters which appear to be fairly constant for the smut collected from many hosts: Echinulate chlamydospores (spores); similarity in spore measurements; germination of the chlamydospores as in the genus Ustilago; and similarity of the symptoms which are indicated by long, black stripes containing chlamydospores principally located in the leaves and stems of the hosts.

Granting that there is but one morphological species parasitizing the different hosts, the physiology of the fungus or the problem of physiologic forms (physiologic races or physiologic species) has remained unsolved and this investigation was undertaken partially to solve the problem through an attempt to answer the following questions:

1. Are there physiologic forms of *U. striaeformis*?
2. Specifically, will germinated chlamydospores removed from timothy *Phleum pratense* L., infect seedlings of redtop, *Agrostis palustris* Huds.?
3. Will germinated chlamydospores removed from redtop infect timothy seedlings?
4. Will reciprocal inoculations show infections similar to inoculations within these two host species?
5. Are the morphological characters of the smut organism on different hosts similar?

COMMON NAME

Leaf smut of timothy is the common name by which this disease has generally been known on each of the different grass hosts in America. This common name was first employed by Trelease (7) in 1882. Pammel (6), in 1901, reported it as *timothy smut* but Rostrup, in Denmark, (Lind, p. 267) spoke of it as grass smut (*"Grassernes Stinkbrand"*). This smut has been reported on 23 different genera and 40 species of grasses, other than timothy, from Europe, America, and Australia. Furthermore, the writer (1) has shown that the organism is not wholly confined to leaves but is systemic, as hyphae and chlamydospores have been located in rhizomes, culms, leaves, and floral parts of grasses. Thus the usage of leaf smut and its association with timothy alone are misleading. So, to conform with the facts, the common name *leaf smut of timothy* should be discontinued and *striped smut of grasses* be substituted.

HISTORICAL

Osner (5) was the first to report results of inoculations with chlamydospores of *Ustilago striaeformis* but he did not report reciprocal and multiple inoculations, the results of which are necessary to determine physiologic-form specialization. Furthermore, infection studies could not have been properly conducted since the proper conditions for germination of the chlamydospores, the locations of the infection area (seedling infection), and the life history of the organism were then unknown.

Lind (3) stated: "It has not yet been proved whether all the said forms are really to be joined into one species, still such morphological differences as might condition a different species do not occur."

Liro (4) has presented a review of the classification of this organism and has shown the need for an investigation of physiologic-form specialization. A translation follows: "It is difficult to recognize the various species of this fungus and one cannot help but wonder whether the mycology of *Ustilago striaeformis* has definitely given so much deception that it will take considerable labor and pains before we can satisfactorily learn to recognize the sub-species of this group-species. But first of all, the biology of the species, concerning which very little is known in literature, must be thoroughly investigated."

FIELD OBSERVATIONS ON THE HOSTS

During the past eight growing seasons, 1920–1927, inclusive, the writer made field observations and collections in Wisconsin, Iowa, Illinois, New York, Pennsylvania, Maine, New Hampshire, Vermont, Massachusetts, and Connecticut. These observations were made specifically to determine the existing host range and to collect spore materials for experimentation. They may be partly summarized as follows:

1. In the various meadows, pastures, and lawns, timothy and redtop plants, together with those of other grasses, had been growing in contact with one another for several years. The species of plants smutted may be grouped:
   - A. Timothy infected with smut, but all the redtop and other grasses smut-free.
   - B. Redtop infected, but the timothy and other grasses smut-free.
   - C. Smutted timothy and redtop in the same field with other species of healthy grasses.
   - D. Timothy and redtop smut-free, but other species of grasses smutted.
   - E. No smutted grass to be found in the plat.
2. In general, only one grass host was severely parasitized at a given station or plat. If other smutted grasses were present, the plants were generally scattered and in the minority. From these generalizations,

it seemed that there were some evidences to show the presence of physiologic forms in the field.

MATERIALS AND METHODS

The timothy and redtop seeds, from which the seedlings were incubated for inoculation, were collected from the following sources:

1. A seed firm at Boston; 2. White mountain timothy from New Hampshire; 3. An Iowa grower of timothy seed; 4. Collections from fields in Wisconsin, Massachusetts, and Connecticut.

The redtop was *Agrostis palustris* Huds. (*A. alba* L.). Other varieties of this species were not employed in the seed collections.

All seeds had been stored for one or more years before they were germinated for experimental purposes. It has been shown (1) that, under optimum conditions, the chlamydospores of *U. striaeformis* seldom, if ever, remain alive more than one year. Thus, it seemed unnecessary to sterilize the seeds, as the seedlings were considered free from infection by any chlamydospores which might have remained attached to them. However, checks were prepared by transplanting uninoculated seedlings incubated from each of the seed collections.

The spore materials were collected from twelve different stations in four different States, but, as shown in table 1, most of these stations were located in Massachusetts. This range was considered sufficiently wide in scope to include any physiologic forms of the fungus that might parasitize either host. Furthermore, spore materials were collected in 1922 and 1924 from grass plants previously removed from fields in Wisconsin and transplanted in the pathological garden at the Massachusetts Agricultural College. When collected, most of the spore materials were within living, green leaves and stems of the hosts. When each sample of spore material was removed from the host, it was placed in a paper packet which was folded and properly labeled. Special care was taken to prevent the spores in one packet from being transferred to another. The collections were made separately and the packets not allowed to come in contact with each other. Spore materials were removed also from artificially inoculated plants in the greenhouse by employing inocula removed from the same host species. These are indicated in table 1 by the numbers 4, 6, 8, and 11.

Most of the spore materials were transferred from the packets to damp filter paper within covered jars and stored at room temperature, 20° C. The jars consisted of Petri dishes and glass-stopper bottles of various sizes. The filter paper in these bottles was kept moist by occasionally adding a small amount of cool, boiled tap water. Likewise, fifty of these spore materials were prepared, but inocula were used from only 12, as indicated in table 1. The others were too contaminated or the spores did not germinate

TABLE 1.—*A table showing the localities, dates, and hosts from which Ustilago striaeformis was collected for inoculum. Also, the dates and percentages of spores germinated in these collections*

Inoculum number	Host	Collection		Germination		Remarks
		Locality	Date	Date	Per cent	
1	Timothy	Windsor, Conn.	7– 6–24	2– 3–25	50	Dead infected leaves and stems stored
2	Timothy	Amherst, Mass.	5–26–26	2– 7–27	88	Infected young plants
3	Timothy	Madison, Wis.	5– 4–25	2–26–26	90	Smutted plants transplanted from Wisconsin
4	Timothy	Madison	5–28–26	10–30–26	90	From plants artificially inoculated in the greenhouse
5	Timothy	Windsor	6– 6–25	2–26–26	85	Collected from two stations
6	Timothy	Amherst	6–25–26	10–30–26	50	From inoculated plants
7	Timothy	Amherst	5–28–26	10–30–26	75	
8	Timothy	Amherst	5– 8–26	10–30–26	99	From artificially inoculated timothy plants
9	Timothy	Ithaca, N. Y.	8–20–26	10–30–26	50	Old infected leaves dried 30 days before storage
10	Redtop	Windsor	7– 6–24	2– 3–25	80	Spore materials stored on the surface of soil
11	Redtop	Amherst	6–23–26	11–20–26	99	Artificially inoculated redtop
12	Redtop	Amherst	6–30–26	2– 3–27	99	Collected from the field
13	Redtop	Madison	6–31–24	1–13–25	80	Smutted plants transplanted from Wisconsin
14	Redtop	Amherst	10–10–24	6– 1–25	85	Infected seedlings stored

sufficiently for investigational purposes. It would seem that the geographic distribution of these 12 spore materials was sufficient to include any widely distributed physiologic form of this smut. The dates on which the spore germination tests were made, together with the percentage that germinated, are also shown in table 1. The methods employed in the inoculations were those which have already been described by the writer (2). Both germinated and ungerminated chlamydospores were placed on the coleoptiles of seedlings submerged in water. Furthermore, seedlings grown from hull and hulled seeds were employed, but the final results sought were the same, regardless of the hulling. However, a higher percentage of infected plants was obtained by removing the hulls in one inoculation (Table 2, A). Seedlings of different ages and lengths of coleoptile were inoculated. The age of the seedlings was considered to be the number of days between the date on which the seeds were set to germinate in distilled water and the date their seedlings were inoculated. This period, together with the operation of other factors such as heat, light, and viability of the seeds, determined the length of the coleoptile. Seedlings with coleoptiles longer than 4 mm. were not inoculated.

Seedlings were never planted twice in the same greenhouse soil for fear that some of the ungerminated chlamydospores falling from seedlings of a previous planting might infect subsequent ones.

The water-holding capacity of the soil could not be satisfactorily controlled, but an effort was made to retain it at 30 per cent of its holding capacity as figured on a dry basis.

By observing the above precautions, the conditions for infection, together with the purity of viability of the inoculum and seed, seemed sufficient for experimental purposes.

INOCULATIONS

Several preliminary tests were made in which inoculated timothy and redtop seedlings were transplanted in plats located in the pathological garden (table 2, series A, I, J, K). As the results of these inoculations in the open were afterwards verified by others in greenhouse beds, the remainder of the work was performed in the greenhouse, where some of the environmental conditions could be controlled and the plants were little influenced by the change of seasons.

The first observation of the inoculated seedlings was generally recorded about six weeks after they had been transplanted. Thereafter, observations and records were made fortnightly. In some series, the infected plants were removed as soon as they were observed; in others, they were marked by placing wooden labels in the soil at their sides. However, only one case was recorded in which infection was observed before five weeks

had elapsed after the inoculations. It seemed necessary, though, to continue the observations until most of the inoculated plants had developed stools and floral parts, for it was often observed that only stools and floral parts showed symptoms of the disease.

A symptom previously unknown to the writer developed in several inoculated timothy plants. The plants were stunted and the stems twisted similar to those of wheat when infected by the wheat nematode, *Thylenchus tritici* (Steinbuch) Bastian. In one case, mycelium of the smut was located in these plants and chlamydospores had formed, but no nematodes could be found.

CHLAMYDOSPORE MEASUREMENTS

Davis (1) reported that the chlamydospores from timothy and redtop were about the same length, but those from redtop were slightly wider (timothy, 8.4 x 11 microns; redtop, 9.3 x 11 microns). Fresh chlamydospores were collected in Wisconsin, Connecticut, Massachusetts, New Hampshire, and New York and measured during the spring, summer, and fall for two years. Also, chlamydospores from each inoculum indicated in table 1 were measured. No method was found whereby the chlamydospores of either host could be differentiated by relying on morphologic characters alone. More often, the chlamydospores of redtop were the broader and of a deeper or intenser color. Sometimes, smutted redtop collections could be differentiated from those of timothy by the deep chocolate color of the chlamydospores. The sizes of chlamydospores varied with the seasons, as those from both hosts were somewhat larger in the early spring and late fall than in midsummer.

In each series, the number of seedlings inoculated and the percentage of infected plants are recorded in table 2. In series A, 220 timothy plants and 204 redtop seedlings, or a total of 424 seedlings, survived after being inoculated and transplanted. In series E, each of the five lots was inoculated with chlamydospores from a different source and 1508 seedlings survived. In B and C, timothy inoculum number 5 from Connecticut infected timothy seedlings incubated from seeds collected in Wisconsin and Connecticut; timothy inoculum 7 from Amherst infected seedlings incubated from seeds collected in Massachusetts and New Hampshire; inocula 11 and 12 from redtop collected at Amherst infected seedlings incubated from redtop seeds collected in Massachusetts, New Hampshire, and Connecticut.

In series W, it is to be noted that timothy inocula collected at Madison, Amherst, and Ithaca infected timothy seedlings from seeds collected in Massachusetts; also, that inoculum from redtop collected at Amherst infected seedlings from redtop seeds collected in Iowa. Likewise, various other combinations in the inoculations are shown in table 2.

TABLE 2.—*Table showing the sources of inocula and seed; dates of inoculation and planting, together with percentages of infection in 16 series of inoculated timothy and redtop seedlings*

Series	Source of inoculum	Source of seed	Date inoculated	Date planted	Seedlings inoculated		Percentage infected		Remarks
	(Timothy)				Timothy	Redtop	Timothy	Redtop	
A	Ser. 1, Conn.[1]	Iowa	6– 8–25	6–22–25	220	204	18	0	Preliminary test
B	S. 5, Conn.	Wis.	2–24–26	3– 2–26	48	60	12	0	Duplicated the following week
C	S. 5, Conn.	Conn.	3–18–26	3–26–26	161	119	10	0	
D	S. 3, Wis.	Iowa	3–28–26	4– 3–26	301	219	10	0	Duplicated with T.5 20 per cent infection
E	S. 4, 6, 7, 8, 9, Wis., N. Y., Mass.	Mass.	11– 3–26	11–10–26	806	702	9	0	Each showed infections
F	S. 9, N. Y.	N. Y.	2– 7–27	2–14–27	1437	219	20	0	
G	S. 4, 7, 2, Wis., Mass.	N. H.	2– 7–27	2–14–27	1337	711	8	0	Each showed infections
H	None, Checks	Each of the above	Same as Ser. A to G	Same as above	About 100 each	About 100 each	0	0	Checks all free from smut
	(Redtop)								
I	S. 10, Conn.	Wis.	6– 8–25	6–22–25	62	46	0	9	Preliminary test
J	S. 14, Mass.	Iowa	6– 8–25	6–22–25	24	84	0	37	Preliminary test
K	S. 13, Wis.	Iowa	2–13–25	2–21–25	44	60	0	12	Preliminary test
L	S. 11, Mass.	Conn.	11– 3–26	11–10–26	163	139	0	10	
M	S. 12, Mass.	Mass.	2– 6–27	2–14–27	137	433	0	9	
N	S. 12, Mass.	N. Y.	2– 7–27	2–14–27	110	99	0	11	
O	S. 11, Mass.	N. H.	2–13–27	2–20–27	92	166	0	18	
P	S. 12, Wis.	N. Y.	2–13–27	2–20–27	73	161	0	33	

[1] S. 1 refers to series 1 as shown in table 1, in which the chlamydospores were collected in Connecticut.

The percentage of infected seedlings was computed from the number of seedlings of the susceptible host inoculated and not from all seedlings inoculated. As in series a, table 2, 424 seedlings were inoculated of which 220 were timothy and, of these 220, 36 or about 16 per cent were infected, but redtop showed no infection. Where several inoculations were made in one series (Table 2, series E), the percentage of infection expresses that part of all the inoculated plants of one host which were infected. From table 2 it is to be noted that the percentages of infection in the various inoculations varied from 8 to 37. This was probably due to a variation of uncontrollable factors, such as differences in the stages of the seedlings and viability of the chlamydospores which were unavoidably removed from different sori in the spore materials; variation of temperature, sunlight, moisture, soil reaction, and fertility. However, the percentages of infected plants were sufficient to show that when the timothy and redtop seedlings incubated from seed collected in Iowa, Wisconsin, Massachusetts, Connecticut, and New Hampshire were inoculated with viable chlamydospores collected from these two hosts in Wisconsin, Connecticut, New York, and Massachusetts chlamydospores from timothy infected only timothy and those from redtop infected only redtop.

REACTION IN AGRONOMIC STRAINS OF TIMOTHY

The foregoing experiments had shown physiologic forms in *U. striaeformis* on two hosts, but it would seem that further evidence were needed to answer the following questions: Are some agronomic strains of timothy susceptible to this smut fungus? Are they resistant? Are they immune? Are there physiological forms of the smut fungus parasitizing timothy?

The following collections of timothy seed were made, in addition to the numbers indicated in table 2: Wisconsin, 3; New York, 2; Massachusetts, 7. Also, C. H. Myers of Cornell University furnished seed of his agronomic strains: 4081, 4001, 4123, 4003, 4031, 4078, 4079, 4059, 1777, 1676.

The spore materials were those indicated in table 1 and others, making a total collection from stations in each State as follows: Massachusetts, 5; Connecticut, 2; New York, 2; Wisconsin, 2.

The methods of inoculation were those described in the foregoing pages of this paper. The agronomic strains were inoculated with but one sample of inoculum collected in each State. Infected plants were observed in each of the inoculations. The artificial infection varied from 70 to 1 per cent. The agronomic strains were arranged in the order of their resistance, beginning with the least resistant: 4079–R1; 1676–R2; 4123–R3; 4001–R4; 1775–R5; 4081–R6; 4003–R7; 4078–R8; 4031–R9; 4059–R10.

No agronomic strains of timothy were found immune from the spore forms of *U. striaeformis* employed and no physiologic strains of the fungus were detected parasitizing this host species.

DISCUSSION

It is possible that collections from stations of a wider geographic distribution, or in foreign lands, may reveal physiologic strains of *U. striaeformis* parasitizing timothy. One can conceive the insurmountable task before the investigator if all possibilities are removed. However, if such strains should be demonstrated in the future, the physiologic forms of this smut parasitizing timothy and redtop might better be known as *biotypes* and physiological races or forms applied to those forms of the smut fungus on a single host species.

SUMMARY

1. *Ustilago striaeformis* is a Latin binomial which has been assigned by mycologists and pathologists to a smut fungus parasitizing about 40 of our grasses. This classification was based on a similarity of the symptoms and chlamydospores as found on each of the hosts.

2. The common name of the disease, *leaf smut of timothy,* should be discontinued and *striped smut of grasses* substituted.

3. Lind and Liro stated that an investigation ought to be made to determine whether this smut was of many or of one physiologic form as well as morphologic species.

4. Field observations showed some evidences of physiologic specialization.

5. This investigation was concerned with two hosts, namely, timothy and redtop. After-ripened chlamydospores from each of these hosts were employed as inoculum.

6. Chlamydospores were collected from 7 stations in Massachusetts; 2 in Iowa; 3 in Wisconsin; 1 in New York; and 3 in Connecticut. These chlamydospores were after-ripened (incubated) from 2 to 9 months and tests indicated 50 to 99 per cent germination. Of the 50 spore collections thus incubated for experimental purposes, only 14 were usable when after-ripened. The geographic distribution of these 14 collections was considered wide enough to include any widely distributed physiologic form of the smut which might exist in our north-central and eastern agricultural districts.

7. The seedlings inoculated were incubated from seeds of timothy and redtop collected in Iowa, Wisconsin, New York, Massachusetts, Connecticut, and New Hampshire. The geographic distribution of the seeds was considered wide enough in scope to include any widely cultivated agronomic strain of timothy which might be immune from or decidedly resistant to this smut fungus.

8. Reciprocal inoculations and inoculations within these two host species were performed on seedlings.

9. From observations and data which were recorded in table 2, these statements seem warranted:

A. Chlamyspores removed from timothy seldom, if ever, infect redtop, but may infect timothy seedlings.
B. Chlamydospores removed from redtop seldom, if ever, infect timothy, but may infect redtop seedlings.
C. There are at least two physiologic forms of *U. striaeformis*, one parasitizing timothy and one parasitizing redtop.

10. No definite morphologic characters were found by which the chlamydospores of the timothy form could be differentiated from those of the redtop form. However, those from redtop may sometimes be distinguished by their deep chocolate color.

11. Agronomic strains of timothy were inoculated and none was found immune from the smut fungus, the inoculum of which was removed from timothy. No physiologic strains of the fungus were detected parasitizing timothy.

MASSACHUSETTS AGRICULTURAL COLLEGE,
AMHERST, MASSACHUSETTS.

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STUDIES ON THE RELATION OF TEMPERATURE TO THE GROWTH, PARASITISM, THERMAL DEATH POINTS, AND CONTROL OF MYCOGONE PERNICIOSA[1]

EDMUND B. LAMBERT

INTRODUCTION

It has been known for more than a quarter of a century that the disease of cultivated mushrooms known in France as "la mole" and in the United States as "bubbles" is caused by *Mycogone perniciosa* Magnus. In congested centers of mushroom growing this disease has become a limiting factor and it is probably conservative to estimate the annual loss in Pennsylvania at 15 per cent of the potential crop, or about 1,500,000 pounds of mushrooms. Experiments and observations have been made to determine possible sources of inoculum and the efficacy of formaldehyde as a fumigant and a soil disinfectant (1, 2, 3, 4). But there have been no controlled experiments made to determine the effect of environmental factors on the development of the pathogene. Because of the importance of temperature in mushroom culture and the ease with which growers can control it in a modern mushroom house, the writer has made a series of experiments to determine the relation of temperature to the growth of Mycogone and its capacity for infection and also to determine its thermal death points when exposed for different lengths of time. It was found to be killed by prolonged exposure to moderately-high temperature. This suggested further experiments which were made to determine the feasibility of eradicating Mycogone from casing soil by means of the heat generated in mushroom houses during the final period of fermentation of the manure.

RATE OF GROWTH AND INFECTION

The temperature in mushroom houses during the period of sporophore formation is usually held between 10° and 20° C. (50° and 68° F.). However, during hot spells in late spring or early fall the grower is unable to control the temperature and it may remain as high as 21° to 24° C. (70° to 75° F.) for several days. Many growers have noticed that bubbles are most prevalent during or shortly after these hot spells and assert that they are never bothered with more than an occasional bubble in houses which have been kept below 13° C. (55° F.) after casing. To throw additional light on this question experiments were made under controlled conditions

[1] The writer wishes to express his appreciation to Dr. L. A. Hawkins, Mr. R. C. Wright, and Dr. J. I. Lauritzen for the use of constant-temperature rooms and incubators and to Mr. J. F. Brewer for the drawings and the photographs.

to determine the effect of temperature on the rate of growth of *M. perniciosa* in pure culture and on the infection of mushrooms growing at different constant temperatures in artificially-infested soil.

As in Smith's (3) cultures, the fungus grew most rapidly when subjected to temperatures between 20° C. and 28° C. (68° and 82° F.), which is above the normal range of temperatures for growing mushrooms. At 15° C. (59° F.) growth was very slow and at 10° C. (50° F.) there was only a trace of growth (Fig. 1). From this we may conclude that the

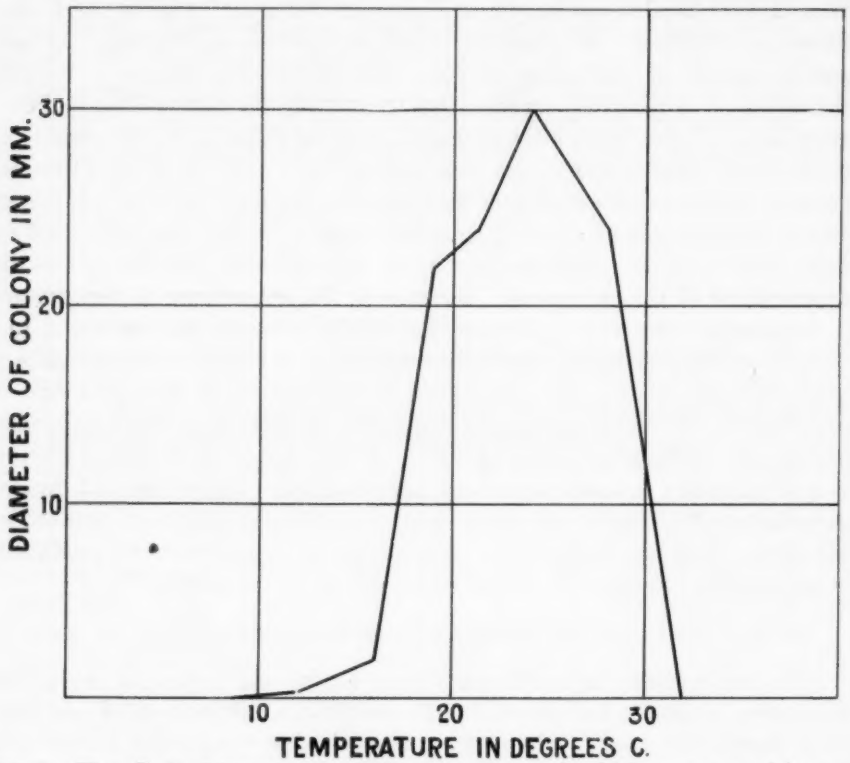

FIG. 1. The effect of temperature on the rate of growth of *Mycogone perniciosa* on Thaxter's agar; measurements were taken 7 days after inoculation.

organism spreads more slowly over the beds as the temperature approaches 10° C. (50° F.). But the formation of sporophores of *Agaricus campestris* also is markedly retarded as the temperature approaches 10° C., as shown in figure 2. Therefore, further experiments were made to determine if infection is diminished by low temperatures. In these experiments twelve mushroom cultures in aluminum cans were cased with artificially-infested moist soil and twelve were cased with Mycogone-free soil as checks. The

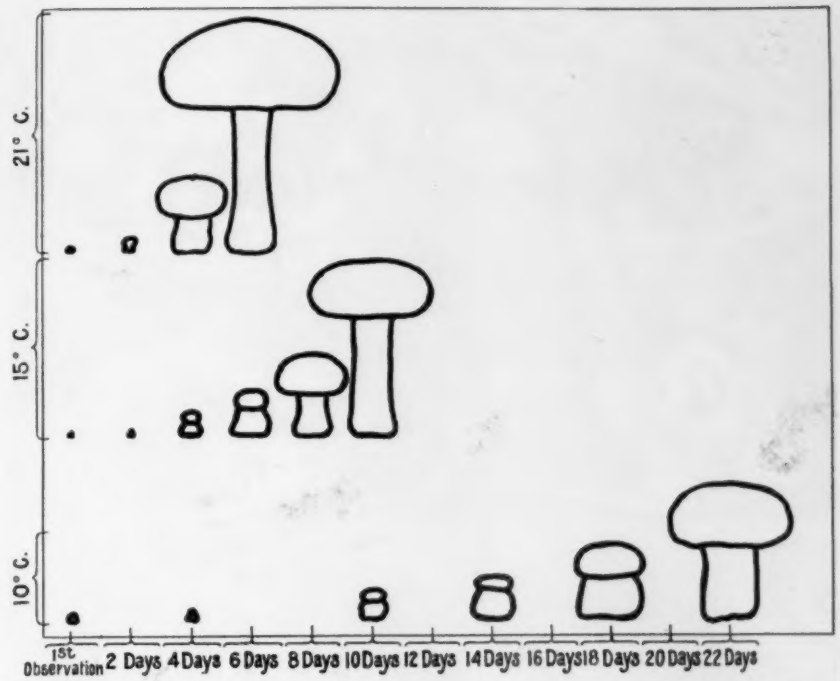

FIG. 2. The effect of temperature on the rate of growth of sporophores of *Agaricus campestris* var. "Snow White"; diagram based on the average of measurements taken from several specimens at each temperature.

cans were then placed in rooms in which constant temperatures were maintained at 21° C., 15° C., and 10° C. (70°, 60°, and 50° F.). There was 100 per cent infection in the eight cultures which were infested and held at 21° C. and at 15° C., while, at 10° C., there were more normal than infected mushrooms. There also was only a partial infection in cultures which had been 100 per cent infected at 21° C. and subsequently cleaned of bubbles and placed to grow again at 13° C. and 10° C. The cultures illustrated in figure 3 are typical of the results obtained. These experiments substantiate the observation of the growers that Mycogone is retarded to a greater extent than mushrooms by low temperatures and indicate that, even in the presence of an excess of inoculum, less bubbles may be expected at temperatures approaching 10° C. than at temperatures above 15° C.

THERMAL DEATH POINTS

According to the present practice, mushroom manure is fermented in such a way that all of the compost is subjected to comparatively high temperatures at one time or another. Outdoors, a large portion of the com-

FIG. 3. The effect of temperature on the infection of *Agaricus campestris* growing in soil which had been generously infested with *Mycogone perniciosa*, strain 13A.—Culture A was cased with Mycogone-free soil and incubated at 70° F.; culture B was cased with infested soil and incubated at 70° F.; culture C was cased with Mycogone-free soil and incubated at 60° F.; culture D was cased with infested soil and incubated at 60° F.; culture E was cased with infested soil and incubated at 50° F.

post heap usually reaches temperatures of 60° to 75° C. (140° to 165° F.) for several hours at a time and inside of the house the beds are made with warm compost and the temperature continues to rise for a few days after they are made, often reaching 60° C. (140° F.). The air temperature inside the house, especially near the ceiling, may go as high as 50° C. (120° F.) for 24 to 48 hours. The question naturally arises, can *M. perniciosa* withstand these temperatures and persist in the manure? Several experiments were made to clear up this point. Preliminary tests indicated that pure cultures of Mycogone are more easily killed by high temperatures in sterile soil and sterile manure than in agar. Further experiments were therefore made to determine the temperatures at which cultures on agar in test tubes would be killed when exposed for different lengths of time. The transfers were made on Thaxter's agar from parent cultures about ten days old. As a precaution against drying out, large blocks of agar were transferred from the parent cultures and inverted on the fresh agar slants

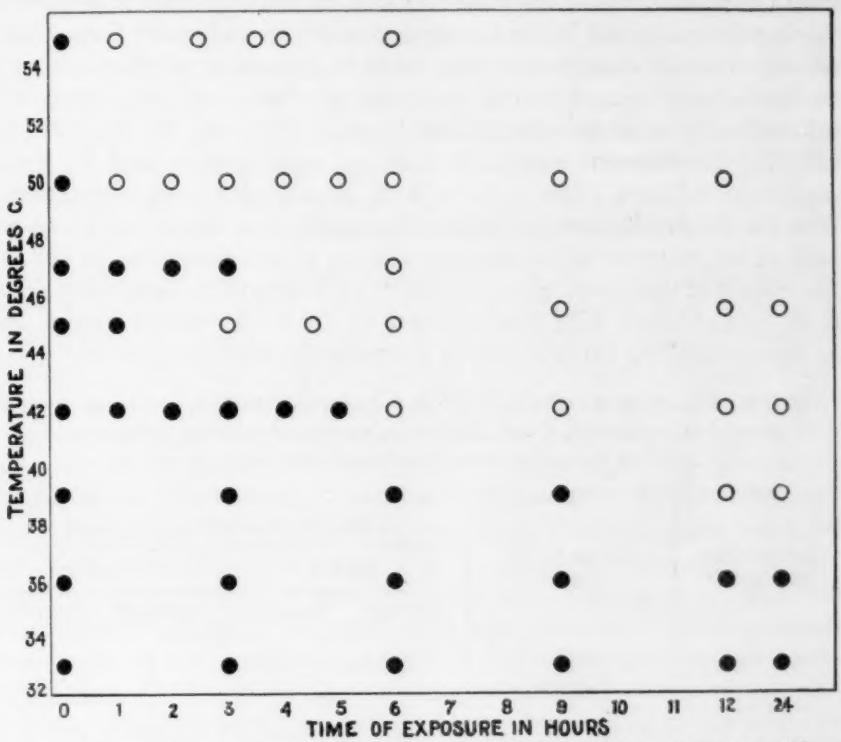

FIG. 4. The thermal death points of *Mycogone perniciosa* when exposed to different temperatures for different lengths of time; cultures were made on Thaxter's agar and the black dots indicate at least one live culture out of the four exposed, while the circles indicate all cultures dead.

so that an abundance of chlamydospores and Verticillium spores was buried in the agar. As an additional precaution beakers of water were placed in the incubator and at the higher temperatures the tubes were capped with tinfoil while they were heated. The results of this series of experiments are shown in figure 4. It is evident that Mycogone is quite sensitive to prolonged exposure to moderately-high temperatures. Under the conditions of these experiments vigorous cultures failed to survive exposure to temperatures no higher than 42° C. (108° F.) for periods of more than 6 hours. It therefore seems highly improbable that the pathogene can remain alive in actively fermenting manure.

EXPERIMENTS WITH HEATED SOIL

The results of the preceding experiments indicate that even the air temperature in the upper part of a well-managed mushroom house is high enough during the fermentation period to kill Mycogone spores. This suggested the possibility of utilizing this heat to eradicate soil infestation by placing the casing soil inside the mushroom house during the fermentation period. Several experiments were made to determine whether soil could be successfully treated in this way. In one series of tests, artificially-infested soil was subjected to temperatures of 52° C. and 45° C. (126° and 113° F.) for different lengths of time and subsequently used for casing mushroom cultures. The cultures were then placed under ideal conditions for the development of bubbles, the presence or absence of which was used as the criterion of presence or absence of the pathogene in the soil. The results of these tests, given in table 1, substantiate the conclusion drawn from data obtained with pure cultures on agar. Altogether they seemed to warrant making further tests in a commercial mushroom house.

TABLE 1.—*The effect of heating soil which has been artificially infested with Mycogone perniciosa (strains 48, 8, and 13A) on the amount of infection in cultures of Agaricus campestris, in which this soil was used for casing*

Temperature Centigrade	No. of hours treated	Number of mushrooms growing			
		Trial I		Trial II	
		Infected	Healthy	Infected	Healthy
	Check	6	0	4	0
	6 hours	2	29	0	10
52°	12 "	0	16	0	1
	24 "	0	10	0	6
	Check	33	0	4	0
	6 hours	1	11	1	4
45°	12 "	0	17	0	3
	24 "	0	1	0	22

In these experiments both naturally and artificially infested soils were subjected to the heat generated by fermenting manure.[2] The soil was placed in round metal pans 5 in. deep by 18 in. in diameter. These pans were set in a mushroom house over fermenting manure, with one edge touching the manure. The temperature of the soil rose to 131° F., about halfway between the air temperature (118° F.) and the manure temperature (140° F.). This temperature was maintained over night, about 14 hours. In the morning the house was opened to release the cyanide gas and the temperature immediately began to fall. By the next morning, when the soil was removed from the house, the temperature of the soil had dropped to 108° F. Four sections of bed were cased with this soil: Two with heated soil, naturally infested and artificially infested, and two with unheated soil, naturally- and artificially infested.

Six weeks later there was 100 per cent infection on the artificially infested check plot and on the naturally infested check plot there was about 80 per cent infection, while on both the plots cased with heated soil there was no trace of infection. The high percentage of infection in the check plot cased with naturally infested soil and the complete absence of infection in the corresponding heated plot were of particular interest since they offer at least one piece of evidence indicating that there are not likely to be more resistant spore forms in nature than there were in our artificially infested cultures.

DISCUSSIONS AND CONCLUSIONS

The results of the experiments presented in this paper tend to clear up several phases of the Mycogone problem: They offer a reasonable explanation for the severe outbreaks of bubbles which are so often associated with hot weather, they suggest a method of reducing the loss in infested houses, they indicate that manure probably is not a source of inoculum in mushroom houses in which there is an active fermentation during the final heat, and they suggest a simple and inexpensive method of eradicating *M. perniciosa* from infested-casing soil. The severe infection often appearing in houses which have been overheated during or following a hot spell seems to be due to the fact that the optimum temperature for the growth of *M. perniciosa* is higher than the normal range of temperatures for growing mushrooms, and the comparative scarcity of disease in cool houses seems to be correlated with the fact that under controlled conditions only sporadic infections develop at temperatures approaching 10° C. (50° F.), even in the presence of an abundance of inoculum in the soil. In

[2] The naturally infested soil was garden soil, heavily fertilized with spent mushroom manure for three years. The experiments were made in the houses of the Keystone Mushroom Company, Coatesville, Pennsylvania, and the facilities for making them were kindly placed at my disposal by Mr. L. F. Lambert and Mr. Charles H. G. Sweigart.

view of these facts it would seem advisable to keep the temperature below 13° C. (55° F.) in all houses known to be heavily infested.

Mycogone perniciosa has been shown to be quite sensitive to prolonged exposure to moderately high temperature. This indicates that it probably cannot withstand the temperatures developed in manure during active fermentation, especially during the final heat in the mushroom house. If the manure is left out of consideration, there is considerable circumstantial evidence which indicates that casing soil is the principal source of inoculum. Beach (1) came to this conclusion after three years' observation of conditions in Pennsylvania; and Smith (3), in England, and Beach have shown that formaldehyde can be used successfully to eradicate Mycogone from soil. In practice, however, this method has certain obvious disadvantages and it would seem to be simpler, safer, and less expensive for the average commercial grower to eradicate Mycogone from his casing soil by taking advantage of the low thermal death point of this fungus. The experiments outlined above indicate that usually high enough temperatures are generated in mushroom houses while the manure is going through its final heat. Of course, further work must be done before we can be sure that sufficient heat will be generated in all cases and that there are not heat-resistant strains of *M. perniciosa* in the soil. Perhaps it will be necessary to use artificial heat.

SUMMARY

1. Experiments were made to determine the effect of temperature on the growth of *Mycogone perniciosa* and on infection of mushrooms by this pathogene, the thermal death curve of the organism, and the possibility of controlling the bubbles disease by subjecting the casing soil to heat generated by fermenting manure.

2. The cardinal temperatures for the growth of the organism on Thaxter's agar are 8° C., 24° C., and 32° C. The most vigorous growth was made between 21° C. and 28° C., which is higher than the range of temperature in which mushrooms are usually grown under cultivation.

3. In experiments in which the relation of temperature to infection was tested there was 100 per cent infection in the cultures held at 21° C. and 15° C., but only an occasional diseased specimen appeared at 10° C.

4. In agar cultures *M. perniciosa* was killed by exposure to temperatures of 42° C. (106° F.) or higher for 6 hours or more.

5. The bubbles disease did not develop in mushroom cultures cased with artificially-infested damp soil which had been subjected to temperatures of 45° C. and 52° C. for 12 hours and 24 hours; there were 100 per cent infection in the check cultures and an occasional infection in cultures exposed for only 6 hours.

6. The disease was controlled also by subjecting artificially infested and naturally infested casing soil to heat generated by the normal fermentation of manure in a commercial mushroom house.

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PATHOGENICITY OF *PESTALOTIA* SPP. ON RHODODENDRON[1]

RICHARD P. WHITE

Pestalotia macrotricha Kleb. and *Pestalotia rhododendri* Guba are common organisms on Rhododendron. They follow sun scald on leaves and young stems (Fig. 1, A. B1), where they cause dark brown, zonate spots, later becoming silvery and covered on the upper surface with acervuli. These symptoms also are found on leaves following injuries produced by the Rhododendron lace bug, *Stephanitis rhododendri* Horv., and other types of mechanical and insect injuries (Fig. 1, B2).

It has been shown by Guba (3) that these organisms have been erroneously referred to as *Pestalotia guepini* Desm. Van den Broek and Schenk (6, p. 327) picture this trouble on Rhododendron leaves and twigs and state that young plants may be killed to the ground by it. Clinton (1) also illustrates Pestalotia on Rhododendron leaves on plants imported from France and Holland, and Schmitz (4) discusses the disease as found on cultivated Rhododendron in this country. The photograph in the latter paper is not of such nature that the disease can be recognized. It is significant, however, in discussing the pathogenicity of the organism, that the author considers it secondary in nature to the attacks by aphids on young leaves early in the season.

Schmitz further states that "the usual methods of artificial inoculation were employed and positive evidence was obtained, showing that this species of Pestalozzia is parasitic in nature." His method of inoculation was to seal a glass ring on the upper surface of a leaf with paraffin and beeswax. Spore suspensions were then placed in the cell and a cover glass sealed over the top. This procedure is quite likely to cause injury to the leaf tissue, a significant fact in the light of the experiments reported below.

Tengwall (5), in 1924, reported some inoculations with Pestalotia from Rhododendron. He states: "Infection on living Rhododendron leaves gave positive results." Tengwall did not state his methods, but Miss Doyer (2) describes Tengwall's procedure as follows: Branches were cut off and placed in water. The leaves were then burnt in various places and on these dead areas spores were placed. The abscissed branches were then placed under a bell jar. The fungus sporulated on these injured areas and the area was increased through its action.

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Plant Pathology.

Doyer (2) carried on rather extensive inoculation experiments with Pestalotia from Rhododendrons. Infection experiments without previous injury were always negative. Attempts made to inoculate the leaves of the variety Pink Pearl (*R. Griffithianum*) Wight, and *R. ponticum* L. through needle pricks gave negative results. Parts of leaves were burnt with a hot knife and inoculated. The organism grew in the dead areas and sporulated thereon. It also grew and sporulated on leaf tips killed with steam. No mention is made of any extension of the dead areas resulting from these inoculations. She concludes that Pestalotia is not parasitic on Rhododendrons.

During the course of a study of Rhododendron diseases, *Pestalotia macrotricha* and *P. rhododendri* have been repeately isolated from leaves of *Rhododendron ponticum* and *R. catawbiense* Hoffmgg. hybrids injured by sun scald. *P. macrotricha* has also been isolated from roots, stems, and petioles of plants previously invaded by other organisms. Observations and isolations indicated that *Pestalotia* spp. on Rhododendron were secondary organisms, invading tissue previously injured by mechanical or biological factors. The inoculations reported here on *R. ponticum, R. californicum* Hook., and *R. catawbiense* hybrids, made under a wide variety of conditions, were conducted in order to prove or disprove the pathogenic nature of these organisms.

Root inoculations. Inoculations on the fibrous roots have been repeatedly made both with and without injury, using spore suspensions and mycelium as inoculum. In no case has any infection taken place either on *R. ponticum,* or *R. catawbiense* hybrids grafted on *R. ponticum,* or on hybrid seedlings, with either of the organisms under discussion here.

Stem inoculations. Inoculations with *Pestalotia macrotricha* at the base of stems, near or below the soil level, have always given negative results. The majority of the inoculations in the stem have been made either on the young new growth near the top of the plant or at the growing point. This growth is soft and succulent compared to the woody growth of the previous year. Inoculations at this point, without injury, have always resulted in failure, even when a large quantity of actively growing mycelium was placed directly on the growing point of the plant kept under a bell jar. With injury, positive results have been obtained using mycelium as inoculum and inserting it directly into the wound. Using spores as inoculum, the results have been mostly negative, although some infection has resulted. Figure 1, C, D, shows a canker produced on the growing tip of a Rhododendron hybrid seedling inoculated with mycelium of *Pestalotia macrotricha.*

An attempt was made to cause infection by inserting spores and mycelium from an actively growing culture of *Pestalotia macrotricha* in the cleft made at the time of grafting. Thirty plants were inoculated at the

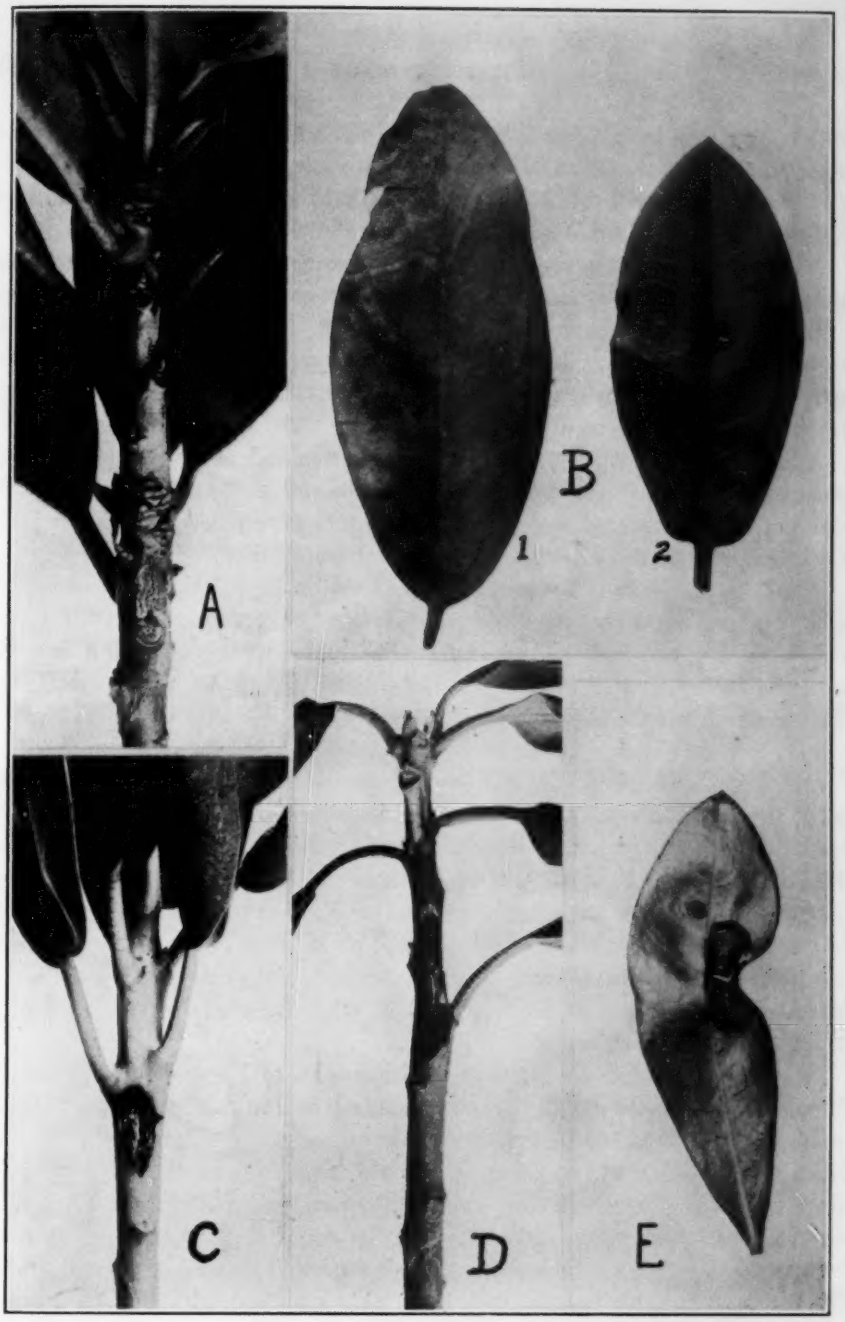

FIG. 1. A. Stem of *Rhododendron catawbiense* hybrid showing *Pestalotia macrotricha* sporulating on sun-scalded areas. B. 1. *Pestalotia macrotricha* on sun-scalded tip of *Rhododendron catawbiense* hybrid. B. 2. Natural infection of *Rhododendron catawbiense* hybrid through crack in leaf tissue. C. Lesion produced by inoculation with mycelium of *P. macrotricha* in new growth of *Rhododendron catawbiense*. D. Same as C. Twelve days after inoculation. E. *Pestalotia macrotricha* on *R. ponticum*. Inoculation by spores through needle pricks on under surface of leaf. Thirteen days after inoculation.

time of grafting by placing spores on the wound made on the *R. ponticum* stock just before the scion of *R. catawbiense* var. *album* was put in place. Thirty plants were held as controls. Callousing was perfect on all the plants and no infection was evident in any of them.

This experiment was repeated, using the same numbers and varieties of under-stock and scion wood, but substituting mycelium for spores. The results were the same. It was again repeated with a similar number of plants, using variety President Lincoln (*R. catawbiense*) as scion material, with identical results. The experiment was repeated with *Pestalotia rhododendri*, with negative results.

Inoculations in the petioles have been confined solely to petioles of mature leaves of the variety President Lincoln and to the use of spores, both with and without wounding. Inoculated plants were placed under bell jars. All attempts to cause infection at this point have failed.

Leaf inoculations. A variety of methods of inoculation of leaves has been used. The early experiments on leaves were conducted on mature leaves, using spores only as inoculum. The spores were placed in a drop of water on the upper leaf surface and the entire plant placed under a bell jar. Negative results were obtained by this method whether with or without prior injury.

Infection was also attempted on abscissed leaves placed in moist chambers. Leaves of *R. ponticum* and *R. catawbiense* var. *roseum elegans* and var. *album elegans* were first washed with mercuric chloride 1–1000 and then thoroughly rinsed in sterile distilled water under aseptic conditions. On the upper surface of these leaves, spores of *P. macrotricha* were placed in drops of water. The chambers were kept at 25° C. No cases of infection resulted, while the leaves were turgid. After ten days the leaf tissue broke down, the leaves turned black and they were invaded by the organism, which sporulated profusely.

It was found that the stomata of the species of Rhododendron used in these experiments occur only on the under surface of the leaves, varying in number from 129 to 164 per sq. mm. Accordingly, experiments were undertaken to determine whether infection could take place on the lower surface of young leaves through the stomata. Spores of *P. macrotricha* were smeared over the lower surface of several leaves of *R. ponticum* and *R. californicum*. The plants were sprayed with atomized water and placed under a bell jar. Negative results were invariably obtained, although the spores germinated and produced a fine weft of mycelium over the surface of the leaves. With injury in the form of slight leaf abrasions, infection took place, appearing after eight days on the upper surface of the leaf as a brown zonate spot.

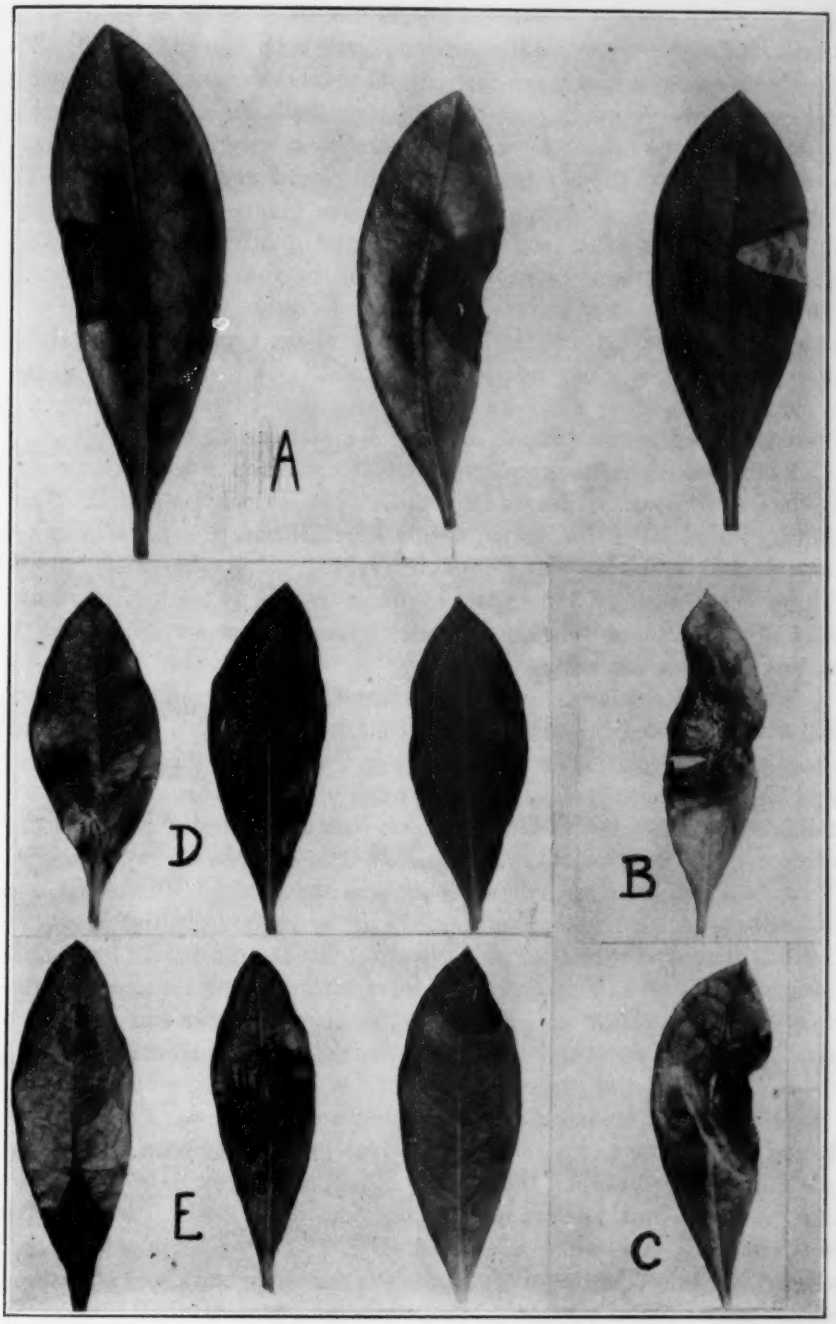

FIG. 2. A. Two leaves inoculated with *P. macrotricha* on burnt areas. Check leaf on right. Ten days after inoculation on *R. ponticum*. B–C. Same as A. Twenty days after inoculation. D. Leaves cut with sterile scalpel. Ten days after injury. E. Same as D, but inoculated with spores of *P. macrotricha*.

A further attempt was next made to inoculate young leaves of *R. ponticum* on the upper surface through cuts made with a sterile scalpel. Three young leaves on each of three one-year-old plants were cut on the upper surface with a sterile needle, one leaf cut near the base, one near the middle, and one near the tip. Spores of *P. macrotricha* were immediately smeared over the cuts and the plants atomized and placed under a bell jar. Three leaves of a fourth plant were cut in a similar manner but were not inoculated. Two days after inoculation, evidence of infection was manifest in the death of the tissue between the cuts on the youngest of the inoculated leaves. Six days after inoculation positive infection was evident on all the inoculated leaves. Brown, circular, zonate spots, typical of natural infections, appeared on these leaves. The check leaves showed no evidence of infection. Ten days after inoculation sporulation was abundant on the more advanced lesions (Fig. 2, D, E). Reisolations were successful.

Further experiments were made by placing a drop of water on the upper surface of *R. ponticum* leaves into which a hot scalpel was placed. The resulting steam killed the tissue, with the result that the latter assumed a watersoaked appearance, followed by subsequent drying and browning. Three leaves, each, of 3 one-year-old plants were thus treated. Two of the leaves on each plant were smeared with spores of *P. macrotricha,* the third leaf serving as a control.

Six days after inoculation, the burnt areas had enlarged and the advancing margin showed the characteristic concentric markings. Ten days after inoculation, sporulation had taken place in the center of the inoculated areas, and 20 days after inoculation the spots had so increased in size as to involve the larger part of the leaf. The check burns remained sterile and of the same size as when produced (Fig. 2, A, B, C). Reisolations were successful.

A final method of securing infection was as follows: With a sterile needle 100 minute punctures were made on the under surface of three *R. ponticum* leaves. Twenty-five similar punctures were made on a fourth leaf to act as controls. Spores of *P. macrotricha* were smeared over the area injured in this way. The plants were sprayed with atomized water and placed under a bell jar. The punctures were barely visible to the naked eye and were not evident on the upper surface of the leaf.

Three days after inoculation, infection was evident on two of the inoculated leaves. The area punctured was browned and invasion of the leaf tissue had extended beyond the area of injury. Thirteen days after inoculation, infection was positive on all three inoculated leaves and sporulation was abundant on the upper surface (Fig. 1, E). The punctures on the check leaf showed on the under surface as minute brown spots and were not visible on the upper surface. Reisolations were successful.

SUMMARY

Pestalotia macrotricha and *P. rhododendri* are weak parasites on *Rhododendron* spp. In the experiments reported here they did not cause infection on roots or on old stems. *P. macrotricha,* however, caused infection on the new growth of previously injured stems; but, even then, infections were variable when spores only were used as inoculum.

On leaves, infection did not take place through the uninjured tissue or through the stomata. Positive infection obtained only through abrasions, scalded areas, and pin pricks. Once established in these injured areas, the organism invaded otherwise healthy tissue.

Various types of injury to Rhododendron leaves form excellent infection courts for these organisms. The most common of these are winter injury, sun scald, and injuries produced by thrips, lace bugs, leaf-chewing insects, and mechanical agents.

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FACTORS INFLUENCING THE MINIMUM INCUBATION PERIODS OF CURLY TOP IN THE BEET LEAF HOPPER

OLIVE SWEZY[1]

Considerable work has been carried on within recent years on the incubation period which must elapse after infection before the beet leaf hopper, *Eutettix tenellus* (Baker), is able to transmit curly top to healthy sugar beets. The problem presented by disease carriers is a complicated one that is intimately bound up, on the one hand, with the interreactions between the insect and the disease-producing organism and, on the other, with this organism and the host manifesting the disease. When this host is a plant which, to a much greater extent than is true of animals, is at the mercy of its environment, factors are introduced having little or no force in problems of animal pathology. Among such factors an important place is held by those which influence the length of the incubation period, both in the insect and in the plant.

Experimental work has shown that the effective incubation period varies within quite wide limits, from the so-called normal incubation period, or the period when at least 50 per cent of infection should be obtained, down to a single infection in as short a time as one hour. It has been found also that under normal conditions a seasonal variation occurs. A number of factors, among which may be mentioned temperature (Severin[2]), have a very direct bearing on the normal incubation periods but, when the minimum incubation periods are considered, it is evident that the same factors do not account for the percentages of infection obtained.

It has been found[3] that under normal conditions "leaf hoppers with an incubation period of one, two and three days transmitted curly leaf to 66.6, 85.2 and 88.8 per cent of the best seedlings" used. This is what we have called the normal incubation period.

In the same report it was shown that with incubation periods of one to four hours no disease was produced in 141 beets, while in 126 beets with incubation periods of four to ten hours 15 diseased beets appeared.

In later unpublished current experiments carried on by Severin slightly different results have been secured. Here an attempt was made to test periods as short as one-half hour, one hour, one-and-one-half hours and then

[1] Bureau of Entomology, United States Department of Agriculture, Berkeley, Calif.

[2] Severin, H. H. P. Minimum incubation periods of causative agent of curly leaf in beet leafhopper and sugar beet. Phytopath. 11: 424–429.

[3] Hunt, T. F. Report of Director. Calif. Col. Agr. Exp. Sta. Rept. 1922–1923: 120–132. 1923.

FIG. 1. Photomicrograph of oesophageal valve between the oesophagus and mid-intestine.

FIG. 2. Photomicrograph of an oesophageal valve between the oesophagus and mid-intestine.

every hour up to four. In these experiments one case of infection was produced with an incubation period of one half hour and one of one hour.

These short incubation periods, occurring as they do in an insect with a well-developed oesophageal valve (Figs. 1, 2) which should prevent regurgitation under normal conditions, present a problem not to be explained by the factors governing the normal incubation periods. A number of experiments have been made to test the evidence for mechanical transmission by the insect. With the 44 beet seedlings used no disease was produced. A study of the intestinal tract of the insect, however, indicates the possibility that this may occur under certain abnormal conditions.

Among the many insects examined for the oesophageal value a single individual was found in which large masses of bacteria were present in the oesophagus anterior to the valve (Fig. 3). These were in two large masses lying in the lumen of the canal. Similar masses of bacteria were to be found in the midintestine, evidently colonies that had been some time in process of formation. The sources of these masses in the oesophagus could not be determined as the valve gave no evidence of being clogged, as would be necessary to allow their egress from the midintenstine. Masses of bacteria of this type have not been found in the sugar beet. Also a comparison of the size of the masses and that of the pumping pharynx would suggest the improbability of these being intact food clumps. A few bacteria may sometimes be found in the lumen of the oesophagus. The growth of these bacteria into a colony of the size of these masses in this position could be due only to a distinctly abnormal or even pathological condition of this part of the intestinal tract. Under such conditions it might be possible for infected beet juice to be ejected from the oesophagus a short time after being taken in, as its free passage into the midintestine might be hindered. If, as seems very probable, this is the case, this condition would explain the occurrence of infection in one-half hour or one hour. It is evidently a very rare occurrence, as a single instance was found among about 250 insects examined.

The food path over which infective juice from the sugar beet must pass before it reaches the salivary glands of the insect from which the infective organism can be injected into a new plant is one that requires some time to traverse. The food must pass down the oesophagus into the midintestine, where absorption takes place. After being taken up by the blood it is carried to the salivary glands from which infective material is injected with the saliva into the plant upon which the insect feeds. The length of time necessary for the food to reach the salivary glands probably has a very direct relation to the minimum incubation period at which curly top may be transmitted to a healthy sugar beet. To determine this, the following experiments were made.

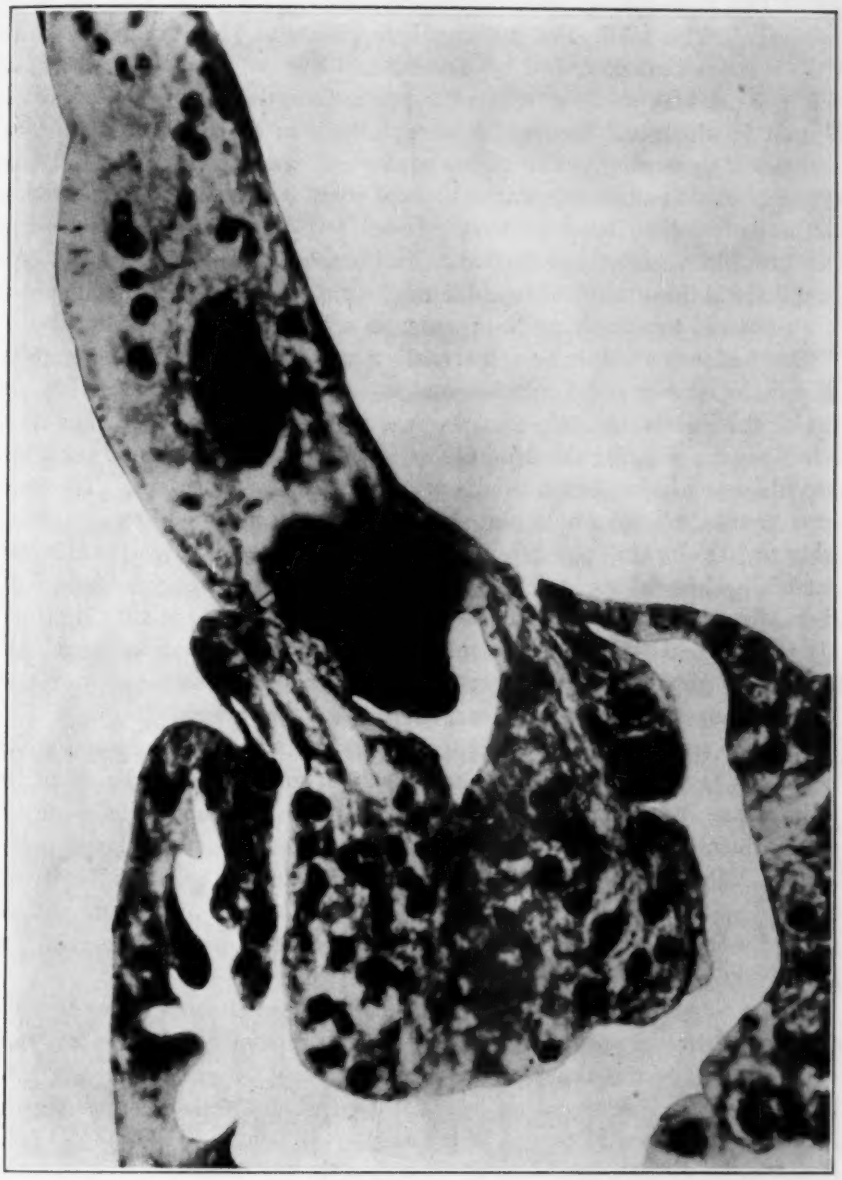

FIG. 3. Photomicrograph of oesophageal valve with masses of bacteria lodged in the oesophagus anterior to it.

Beet leaf hoppers were fasted for about twenty-four hours and at the end of that time a small dish containing the prepared food was placed in their cage. This method of feeding these insects and infecting the plants is the same as that described by Severin and Swezy.[4] The dish was filled with a 5-per-cent solution of beet sugar or sucrose in physiological-salt solution to which had been added enough stain in a 1-per-cent solution to produces a deep color. The stains used were eosin, methylene blue, and trypan blue. The last was a total failure, as it was completely oxidized as soon as it had been taken in by the insect. Of the other two, methylene blue proved the most satisfactory. This stains small granules scattered around the cell midway between the center and the periphery. The stains were prepared by dissolving the powder in a 5-per-cent sugar solution.

The first experiments were carried on under ordinary room temperatures in November and December and it was found that less than 25 per cent of the insects had fed, though some remained in the cage from three to five hours. Placing the cage under a 100-watt electric light raised this percentage somewhat, but still not enough for satisfactory work. To secure better results, the cages were placed in a box heated by two 100-watt electric lights to 100° to 115° F. Even with this, however, not more than 50 per cent of the insects would feed, those used at this time of year being the hibernating forms. The insects were taken from the cage at varying intervals and dissected under a binocular, taking out the intestinal canal and the salivary glands intact. These were placed on a clean slide in a drop of physiological-salt solution and examined under the microscope.

At room temperature it was found that within three hours insects which had fed on the prepared food showed the stain in the epithelial cells of the midintestine and the narrow portion of the malpighian tubules near the opening into the alimentary canal. In those that had been placed under a strong light the stain had been carried through the body cavity within three hours, the muscles of the wings showing a fairly heavy stain. At the end of five hours granules stained with methylene blue could be found in the salivary glands.

In these experiments no attempt was made to get the exact time of feeding, as the food was not removed from the cage until all the insects had been examined; hence the times given may in reality be somewhat less than stated, as all the insects did not begin to feed when the dish containing the sugar solution was first placed in the cage.

Since the feeding activities of these insects are largely conditioned by the temperature of their environment, and since not only the greatest percentage of infection but the minimum time of incubation are found under

[4] Severin, H. H. P., and O. Swezy. Filtration experiments on curly top of sugar beets. Phytopath. 18: 681–691. 1928.

high temperature, it was expected that the time of food absorption would be greatly lessened by high temperature. The first insects from the heated cages were examined at the end of thirty minutes, when the cells of the midintestine showed the characteristic stain. The first appearance of the stain in the salivary glands was seen at the end of one hour and fifty minutes.

In these experiments, like the first ones made, the insects were allowed to feed continuously until the last ones were taken out for examination. In later groups a number were taken from the cage and examined ten minutes later after having been fed the sugar solution. Examined at the end of fifteen minutes subsequent to such feeding, it was found that the stain had already penetrated the epithelial cells of the anterior enlarged portion of the midintestine, the staining reaction being the characteristic one found throughout these experiments. At the end of one hour stained granules could be detected in the salivary glands. No attempt was made to determine how long, after feeding, the stain could be detected in the ejected saliva. Any foreign organism or particles of stain would not necessarily have to remain in the glands the same length of time required for elaboration of the saliva from the materials absorbed from the blood.

In conducting these experiments, use was made of a 5-per-cent sugar solution, since, in previous work, this had been found the most satisfactory medium for feeding the beet leaf hopper under artificial conditions. No direct comparison can be made, of course, between this solution and the unchanged juice of the leaves of the beet upon which the insects had been fed in the experiments to determine the length of the incubation period, as no analysis of the juice of the young beet leaves has been made. With the percentages of sugar, sodium chloride, and methylene blue, it seems unlikely that the contents of the two food materials would be such as to change materially the rate of absorption when taken into the midintestine. If this is the case, then these periods represent approximately the time required under normal conditions for the absorption of food and its distribution through the body.

The question of whether we are justified in comparing methylene blue in a sugar solution with the infective organism in the beet juice is an open one. The rate of absorption would depend largely on the size of the organism unless it was able to effect entrance into the cell by its own exertions. Otherwise, it, like the stain, would be carried passively along by the movements of the surrounding liquids. The fact that ingested material may reach the salivary glands within the short interval of one hour has, however, direct bearing on the minimum incubation period of the curly-top organism in the insect.

If the organism causing curly top is passed unchanged through the body of the insect, it should be able in a large percentage of cases to transmit the disease at high temperatures one hour after feeding. This, however, is not the case, as infection at one hour is very rare. An interval of about twenty-four hours is required before at least a 50-per-cent infection is obtained, and not until the interval has lengthened to three or four days is the maximum infection secured. The time necessary for multiplication of the organism would not account for this, multiplication being necessary only to maintain a continuous infective condition in the insect. Neither can it be said that the small amount of infective material reaching the salivary glands in the first hour would preclude transmission of the disease. A single long-time-infected leaf hopper invariably gives positive results in a very large percentage of cases, while large numbers of insects, 25 to 400 or more to each plant, infected less than two hours, give negative results with rare exceptions, though it is evident that the amount of material injected into the plant is many times that produced by the single insect.

An alternative explanation is found in the fact that a change in the life cycle of the infective organism occurs in the body of the insect and this must be completed before the insect is capable of readily transmitting the disease to a healthy plant. This explanation is not incompatible with the finding of an occasional transmission of curly top within such very short intervals as one or two hours. It is possible for the infective organism to reach the salivary glands so promptly that it remains unchanged and is, therefore, ready to infect a new plant when ejected with the saliva. That this is not an habitual thing, however, is indicated by the small percentage of infection obtaining at intervals of only a few hours.

It seems probable that these two methods of internal mechanical transmission of curly top may account for the occurrence of this disease at its minimum incubation periods. One of these methods is due to an abnormal condition of the intestinal tract which hinders the free passage of food, and the other to the passage of the infective organism unchanged through the body of the insect. This, of course, does not preclude the possibility that other methods of mechanical transmission may occasionally be effective in the transmission of curly top at short intervals.

A SIMPLE METHOD OF INOCULATING THE APPLE

G. A. Huber

During the past two years the writer has had occasion to inoculate many apples with organisms which have been isolated from the surface of normal apples to test their pathogenicity.

Granger and Horne[1] used a method of inoculation in which a cylindrical plug was removed from the apple by a cork borer. After inoculation the same plug was replaced in the cavity and sealed over with melted paraffin. The inoculated apple was treated with absolute alcohol and wrapped in sterile "greaseproof" paper.

Brooks and Cooley[2] made inoculations by forcing the spores and mycelium down into the apple by means of a platinum wire.

Previous investigations, carried out in the Plant Pathology Laboratory at the State Experiment Station, Pullman, Washington, have shown that a very high percentage of decay found in storage apples is caused by infection taking place through mechanical injuries. In order to make inoculations with pure cultures of known organisms, free from contamination, and yet as nearly as possible similar to natural injuries caused by stems, twigs, etc., the writer used the following method, which has proved more satisfactory than any other tried.

The apples are first scrubbed with a brush in running water to remove the foreign matter from the surface. Each apple is then immersed in $HgCl_2$ 1–1000 for several minutes and thoroughly wiped with cotton previously soaked in the same solution and then wrung out. Punctures are made, usually three in each apple, 0.3 cm. in diameter and 0.8 cm. deep. These are made with a steel rod (Fig. 1) 0.3 cm. in diameter and provided with a collar 0.8 cm. from the end of the rod, which prevents it from sinking too deeply into the flesh of the apple. The rod is dipped into 95 per cent alcohol, then drawn through the flame of a Bunsen burner, and immediately held close to the surface of the apple, so that the flame will melt the epidermal wax around the place of puncture. If the burning alcohol is allowed to drop from the rod to the apple, a scald will develop around the puncture. When the alcohol is all burned and the wax is cooled, the rod is plunged into the apple. The inoculum is placed in the punctures and the apple is wrapped in sterile oiled wraps, which retard drying out of the punctures and prevent contamination from air and adjoining objects.

[1] Granger, K., and A. S. Horne. A method of inoculating the apple. Ann. Bot. 38: 212–215. 1924.

[2] Brooks, C., and J. S. Cooley. Temperature relations of apple rot fungi. Jour. Agr. Res. 8: 139–164. 1917.

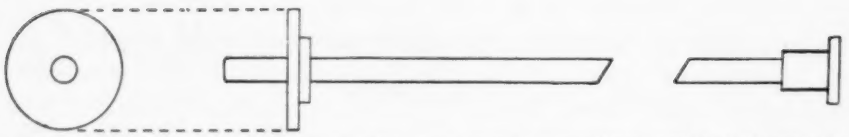

FIG. 1. Schematic drawing of steel rod used in making artificial inoculation punctures.

In order to determine the effectiveness of the melting of the wax previous to the puncturing of the epidermis of the apple, a series of puncture tests were made on apples in which the inoculating rod described above was used.

The apples to be punctured were first sprayed, by means of an atomizer, with a water suspension of spores of *Penicillium expansum* Link. The suspension was allowed to dry on the surface of the apples before puncturing them.

Fifty punctures were made without previously sterilizing the surface of the apples or melting the wax at the place of puncture; fifty punctures were made without previously sterilizing the surface of the apples, but first melting the wax at the place of puncture; fifty punctures were made after sterilizing the surface of the apples for two minutes in mercuric chloride 1–1000 and melting the wax at the place of puncture.

The data obtained in these tests are recorded in the accompanying table.

TABLE 1.—*Results obtained by melting the wax before puncturing the apples for inoculation*

Treatment	No. punctures	No. decayed	Percentage decay
Apples not sterilized; wax not melted	50	50	100
Apples not sterilized; wax melted	50	0	0
Apples sterilized; wax melted	50	0	0

The results of the tests show that the melting of the wax around the place of puncture gives heat sufficient to kill the spores which may be located on the surface or inbedded within the wax. Even though the spores are all killed around the place of puncture, it is practical to wash the apples in $HgCl_2$ 1–1000 before puncturing in order to destroy the spores on the surface which may be wiped into the punctures after inoculation.

DEPARTMENT OF PLANT PATHOLOGY,
STATE COLLEGE OF WASHINGTON,
PULLMAN, WASHINGTON.

TRANSMISSION OF CUCUMBER MOSAIC TO SPINACH[1]

ISMÉ A. HOGGAN

Of the virus diseases of the mosaic group, cucumber mosaic is regarded as having a relatively wide host range among dicotyledonous families. Not only does it affect numerous genera and species of the Cucurbitaceae and Solanaceae, but also individual species belonging to other, more or less unrelated families are known to be susceptible. It is probable that the recognized host range of this disease will become much extended in the future.

It has recently been shown[2] that cucumber mosaic is readily transmissible by the peach aphid (*Myzus persicae* Sulz.) between various members of the Solanaceae. More recently, it has been found by the writer that the potato aphid (*Macrosiphum solanifolii* Ashm.) also readily transmits this disease between tobacco and certain other solanaceous plant species. Furthermore, it has been found that cucumber mosaic is readily transmissible by these two species of aphids to spinach (*Spinacia oleracea* L.), from which host the virus is again recoverable by the same agency. The transmission of this disease to spinach is, in itself, not surprising in view of its recognized wide host range. The chief interest lies in the fact that the resulting symptoms produced on spinach bear a remarkable resemblance to those of "spinach-blight," judging from the descriptions of the latter disease as given by McClintock and Smith[3] and others. Characteristic symptoms of cucumber mosaic on spinach, as observed on young plants under greenhouse conditions, include a progressive yellowing and necrosis of the foliage, marked stunting of the plant, malformation and mottling of the young leaves, and ultimate death of the entire plant (Fig. 1). This apparent similarity of symptoms, together with the identity of the insect vectors in the two cases, is suggestive of a possible relationship between the two diseases. Unfortunately, the writer is not acquainted with spinach blight as it occurs in the field, nor has any material affected with the disease been secured. Consequently, it has not been possible to reach any definite conclusion as to the suggested identity of the two viruses in question.

[1] Cooperative investigation conducted by the Wisconsin Agricultural Experiment Station and the Office of Tobacco and Plant Nutrition, Bureau of Plant Industry, U. S. Department of Agriculture.

[2] Hoggan, I. A. The peach aphid (*Myzus persicae* Sulz.) as an agent in virus transmission. Phytopath. **19**: 109–123. 1929.

[3] McClintock, J. A., and L. B. Smith. True nature of spinach-blight and relation of insects to its transmission. Jour. Agr. Res. **14**: 1–60. 1918.

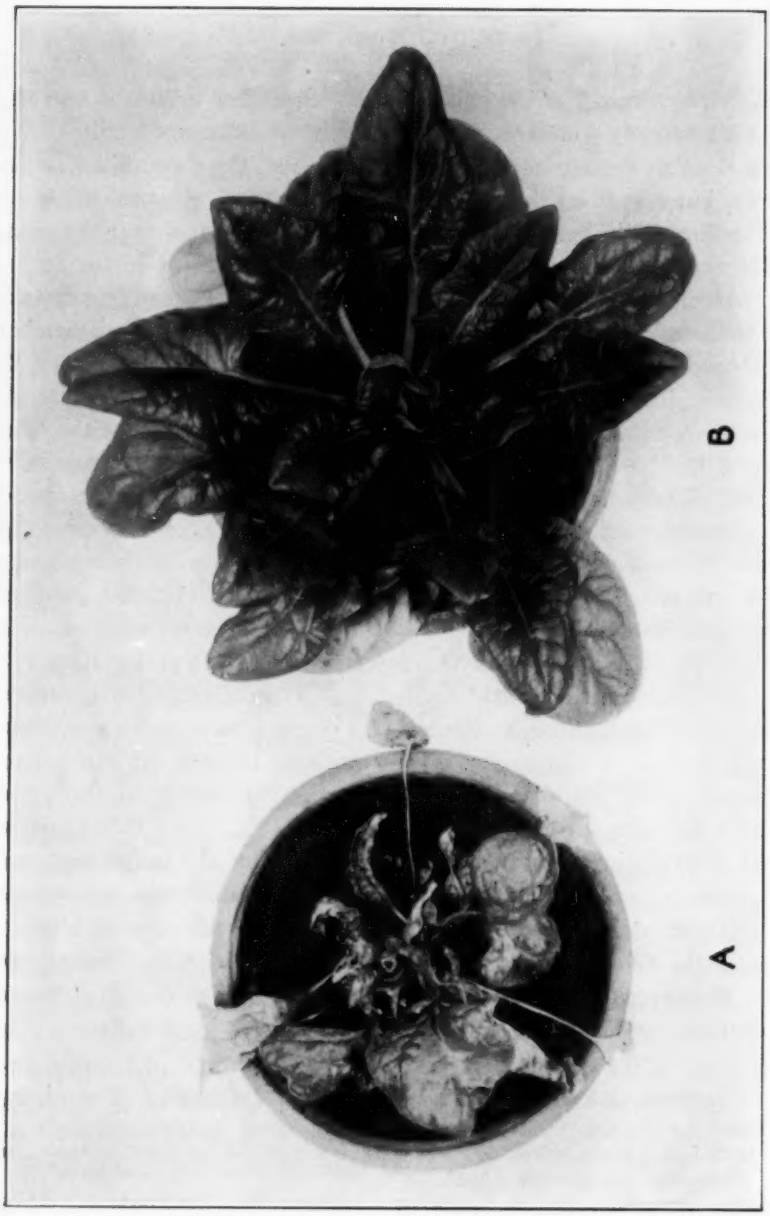

FIG. 1. A, Cucumber mosaic on spinach (variety Victoria), transmitted by *Myzus persicae*.
B, Healthy, mosaic-free plant.

Since the recognition of spinach blight as a disease of the insect-borne virus type, it has been of special interest on account of the claim made by McClintock and Smith that the virus can be transmitted directly by infective parent aphids to their progeny up to the fourth generation. If the virus of spinach blight should prove to be identical with that of cucumber mosaic, our understanding of this puzzling aspect of the virus problem would be greatly increased and simplified. However this may be, cucumber mosaic on spinach is a disease of such striking symptoms that its occurrence is believed worthy of recording. Further studies on the disease are planned, and the principal purpose of this note is to make a request for any specimens of plants known or believed to be affected with true spinach blight, in order that a more exact comparison of the two diseases may be made.

UNIVERSITY OF WISCONSIN,
MADISON, WIS.

PHYTOPATHOLOGICAL NOTES

Sclerospora macrocarpa in barley.—On June 21, 1929, J. Earl Coke gathered specimens of diseased Coast barley near Los Baños, in the San Joaquin Valley, California. The disease appeared to be *Sclerospora macrocarpa* Sacc. Specimens were sent to Wm. H. Weston, Jr., Farlow Herbarium, Cambridge, Mass., who confirmed the identification. The field, consisting of well-drained but rather heavy soil, was sown in the fall and was irrigated at least once to produce the barley crop. Rainfall in that part of California usually is insufficient to produce good grain crops. As the field was inspected after full maturity, casualties among the young seedlings could not be determined. Diseased plants were found uniformly and generally but sparsely distributed throughout the field. The attacked culms yielded spikes which produced no grain, but other culms from the same plant produced normal spikes and kernels but weak, reduced culms. The diseased spikes possessed swollen, distorted, curled awns, and twisted culms about 12 inches in length. The whole culm, including nodes and internodes, was darkened like those attacked by barley stripe (*Helminthosporium gramineum* (R.) Eriks.). The upper leaves frequently were broken into strips or ribbons by the destruction of the tissue between the veins. No conidia, but abundant oospores were observed. Further inspection of the area will be made during the next crop season.

In 1921 this disease was found on wheat in Kings County, in the same general area.—W. W. Mackie, *University of California, Berkeley, Calif.*

A Note upon the Conidial Sclerospora of Maize in South Africa.—A downy mildew of maize was observed in January, 1924, in a small plot cultivated by an Indian near Verulam, Natal. Half the plot at this time was coming into flower and showed about one per cent of diseased plants, while the young plants of the other half were about 20 per cent diseased. The affected plants exhibited the typical signs of a Sclerospora infection as described by Weston,[1] namely, chlorosis and mottling of all leaves but the lower ones, a well-marked jagged margin between the chlorotic and normal tissue of the lower leaves, upstanding position of the leaves, stunting and general weakness of the plants, and, in the older plants, fasciated tassels. Usually on visits during the daytime, there was little evidence of spore production, but this was readily induced in plants removed to the laboratory and kept wet overnight in a saturated atmosphere. Subsequently, similar disease signs were observed in plants of a sorghum cultivated alongside the affected maize.

[1] Weston, W. H., Jr. Philippine downy mildew of maize. Jour. Agr. Res. 19: 97–122. 1920.

Sclerospora was in evidence in the maize in this plot again in the seasons 1924–25, 25–26, and 26–27. Meanwhile, its sporadic occurrence was noted in many localities in the Natal Coast belt and also in the Waterberg district of the Transvaal upon maize, cultivated sorghums, and also the wild *Sorghum arundinaceum* Stapf.[2] Two cases of extensive damage to field crops of maize were observed in April, 1925, at Naboomspruit, Transvaal, and in February, 1928, at Hluhluwe, Zululand.

The direct infection of maize seedlings was readily obtained in the greenhouse by placing pieces of conidium-bearing maize leaves in proximity to the seedlings kept in a saturated atmosphere. In three experiments, 12 out of 16 plants became diseased. In similar experiments, but using diseased *Sorghum arundinaceum* as source of infection, positive infections were obtained; one out of 8 plants tested in October, 1925, one out of 10 plants in October, 1926, and 10 out of 12 plants in January, 1927. In all experiments, adjacent control plants remained free from disease.

If the foregoing experiments in transmission from *Sorghum arundinaceum* to maize may be regarded as significant, we may perhaps look to the former as an overwintering host of this fungus, since under South African conditions this grass is a weak perennial.

A more detailed account of the fungus herein referred to will be published later.—H. H. STOREY and A. P. D. MCCLEAN, *Tanganyika, Africa.*

A bacterium associated with bundle blackening in the balsam, Impatiens balsamea.—During the summer of 1924 it was observed that many of the balsam plants grown for class use in the botanical greenhouse at the University of Wisconsin had rotted at the surface of the ground. Investigation showed that not only had the stem decayed at the base but that some of the vascular bundles in each plant were blackened to the top of the stem. Attempts were made to isolate a possible causal organism by plating from bits of diseased tissue. Several organisms were isolated, including two species of Fusarium; but one bacterium was rather constantly found associated with the black bundles in the stem. The other organisms were found at the base. This bacterium was a moderate-size, actively motile rod which formed colorless colonies. Growth on nutrient agar was rapid, since at room temperature the streak on an agar slant was distinctly visible within 12 hours after inoculation and there was good growth after 24 hours.

Balsam plants were inoculated by puncturing the base of the stem with a needle which had been dipped in a pure culture of this bacterium. Posi-

[2] *Sorghum arundinaceum*, Stapf.—a weak tufted perennial under our conditions—described by Stapf as an annual in the Flora of Tropical Africa, IX, Pt. 1. p. 114; and originally included by him with *S. verticilliflorum* in *Andropogon halapensis* var. *effusus* (Flora Capensis, VII, p. 346).

tive results were secured only when the puncture was made below the surface of the ground. In this case bundle blackening occurred with great rapidity, extending to the tops of the plants, a distance of four to six inches, within 48 hours. In these small plants the black lines were visible through the transluscent stem. Since the punctures were exposed to the soil it was realized that it would be necessary to use sterilized soil in order to prove definitely that this bacterium was the cause of the disease. This was more evident since one of the check plants, which had been punctured below the surface of the ground with a sterile needle, developed blackened bundles. Time was not available for carrying out the experiment with sterilized soil, and, later, the cultures died because they had been left too long without transferring. Either the author or Dr. L. R. Jones, University of Wisconsin, would be pleased to hear from any one who has found a similar condition.—T. D. HOWE, *Table Rock, Nebr.*

A new host of sugar-cane mosaic.—While making inspections of sugar-cane fields in the vicinity of Lima for the mosaic disease during 1929, several instances of mosaic infection of "caña brava" (*Gynerium sagitattum* Beauv.) were observed. To the writer's knowledge, this grass has not been reported previously as a host of mosaic.

Infection of the wild cane has been observed only when it is growing on the borders of sugar-cane fields where mosaic is present. Both large, mature plants and young shoots arising from cut-over patches have been found affected with mosaic, the former showing both primary and secondary infection. The symptoms of the disease on the wild and cultivated hosts are identical. Although artificial inoculations have not been made to prove the identity of the disease on both hosts, field evidence supports it.

In view of the almost universal occurrence of caña brava on the banks of irrigating ditches bordering sugar-cane fields in Peru, the infection of this grass by mosaic adds another factor to be considered in controlling the disease. However, the amount of mosaic so far observed in the wild cane is relatively very small and at present it does not appear to be of great importance in spreading the disease.—E. V. ABBOTT, *Estación Experimental Agrícola de la Sociedad Nacional Agraria, Lima, Peru.*

Peteca and red blotch of lemons.[1]—Preliminary studies of peteca and red blotch (Adustiosis) of lemon fruit have been made with a view to producing the effects artificially. These efforts have yielded a few positive results. Close approximations to peteca breakdown have been secured

[1] Faweett, H. S., and H. A. Lee. Citrus diseases and their control. 582 pp. McGraw-Hill, New York. 1926.

through hypodermic injection of small amounts of orange oil, lemon oil, and geraniol into the albedo tissue. Slight peteca-like effects also were secured by injecting methyl and ethyl alcohols. This leads one to speculate on the possible physiologic origin of the diseases, for the oils occur naturally and the geraniol and alcohols are products of anaërobic respiration. Simulations of red blotch have been effected by touching lemons with amyl formate, amyl valerate, amyl acetate, amyl propionate, and ethyl acetate, all of which esters have been found as products or by-products of anaërobic respiration in apples. Red-blotch effects were produced also by exposing the fruit to a vapor of ethyl acetate for periods of 30 minutes to 2 hours.—L. J. KLOTZ, *Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.*

Separates or reprints of the late Dr. Erwin F. Smith's article, "Fifty Years of Pathology," which appeared in the Proceedings of the International Congress of Plant Sciences held at Ithaca, are available at 80 cents per copy postpaid. The article consists of 34 pages of printed matter and 34 plates, paper cover. The plates include reproductions of about 270 pathologists. The secretary of the Congress took the responsibility of ordering 200 reprints of this paper, to be sold at a price reasonably above cost, with the understanding that any balance, after paying the cost of printing, would be made available for the general expenses of the Congress, if needed therefor, or otherwise used in some way which would obviously have been approved of by the author.

B. M. DUGGAR, *Secretary,*
International Congress of Plant Sciences.

ABSTRACTS OF PAPERS PRESENTED AT THE TWENTY-FIRST ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, DES MOINES AND AMES, IOWA, DECEMBER 28 TO JANUARY 31, 1929, INCLUSIVE

Some properties of furfural in relation to fungicides and herbicides. I. E. MELHUS.

Furfural has a low surface tension, 48 dynes, is unstable, and has a marked affinity for living or dead plant tissue. The volatility of 7 per cent furfural in water is about four times as much as in kerosene. Furfural emulsified in kerosene reduces the volatility of furfural to that of kerosene (31.85 dynes). In dilute solutions (5 per cent), furfural reduces the surface tension of water from 77 to 40 dynes and, consequently, increases the covering and penetrating powers. Furfural emulsified in kerosene (designated as FK 10–90), on the other hand, raised the surface tension less than 1 dyne.

Potato stems soaked for one hour in 7 per cent furfural in water and in kerosene gained weight, while those in furfural and FK 10–90 lost. Quack-grass rhizomes soaked in furfural and FK 10–90 for five minutes lost weight, 6.38 and 1.01 per cent, respectively. The same was true of short pieces of tomato stems. The lethal action, on green tissue, of furfural emulsified in kerosene is increased more than 10 times. Four-and-one-half times as much furfural as water is absorbed in dry apple wood, 3.7 times in green apple, and 3 times in dry red oak. Dry white cedar posts showed 25.96 per cent gain in weight in water, 10.57 in kerosene, 37.68 in furfural, and 15.33 in FK 10–90.

The waste sulphite liquor of paper mills as an adjunct to spray materials. R. H. HURT.

The waste liquor of the sulphite process of paper mills is sold under the trade names of Goulac and Glutrin. Goulac is the powdered form and Glutrin the concentrated liquor. These two forms have the same analysis, the only difference being that Glutrin contains approximately 50 per cent water. These forms are plentiful and cheap, and have been found to be valuable adjuncts to certain spray materials.

The outstanding feature of these materials is that either form makes an excellent emulsifier for home-made oil emulsions. Both forms are very soluble in water and easy to handle. The emulsions thus made are miscible in any proportion with lime-sulphur. It costs approximately one dollar to emulsify a barrel of oil with calcium caseinate and about fifteen cents with Goulac or Glutrin.

The powdered form may be substituted for calcium caseinate in the preparation of dry-mix. It makes a dry-mix which is just as wettable as one made with calcium caseinate and has better suspension qualities. The dry or liquid form when used at the rate of one pound or one quart, respectively, to 50 gallons of solution practically eliminates the chemical reaction between lime-sulphur and lead arsenate.

The Dutch elm disease. CHRISTINE BUISMAN.

In 1920 a serious disease attacked the elm tree in Holland. The symptoms are as follows: In the first part of June the leaves of the whole tree or of some branches suddenly wither and then turn brown, but they do not fall from the tree immediately and the top leaves may not fall for several weeks; the twigs curve; and in the wood conspicuous reddish brown streaks are visible. The tree may die within a year or it may live for several years. Most of the trees affected are from 15 to 40 years of age. Consequently the disease is rather rare in nurseries.

Gradually, the disease spreads through Belgium, France, and Germany; and, since 1927, it has been reported from England. There are no signs of its decreasing in the course of time.

Miss M. B. Schwartz, a Dutch phytopathologist, isolated without exception from the diseased wood a species of Graphium, which she named *G. ulmi*. Healthy wood never yields *G. ulmi*. She stated that this fungus was the cause of the disease but, as her inoculation experiments were not quite convincing, this statement has been doubted for several years. Subsequent investigators, however, could cause the disease with all its symptoms in healthy trees by inoculation with *G. ulmi*. It is likely that the spores of this fungus are spread principally by wind and enter the wood through small wounds. Means of control have not yet been found. The only thing that can be done now is to test the resistance of various species and varieties of elms by inoculation experiments and to propagate the most promising ones.

A future outlet for pathological service. R. P. WHITE.

Plant pathology as related to ornamental plant materials is the most recent field of the science to be seriously considered. The future growth of this field depends upon (1) the recognition of the increasing value of ornamentals to the great mass of our population and the importance of the industry to many of our States; (2) the ability of plant pathologists to gain the confidence of the producers and to dispel their fears concerning domestic quarantines; (3) the realization that this field touches 22 million home owners in the United States and is not limited to a small specialized group of producers; (4) the ability of department heads to gain the sympathy of the directors of our experiment stations toward the field and to receive the financial assistance necessary for research and extension activities.

Outlets for pathological service in the field are enumerated as follows: (1) positions as plant pathologist for ornamentals with many of the experiment stations located in the larger producing States; (2) positions with some of the larger nursery concerns who are able to support a plant pest expert; (3) positions on city or county park commissions who have the responsibility of maintaining the health of the ornamental plant materials used on public properties; (4) positions with "public service" corporations who sell such service to municipalities and private individuals; (5) opportunities as practicing plant doctors in many of the suburban areas where a wealth of valuable ornamental plant material has been planted, the value of which to the owner is many times the actual intrinsic value represented.

Hybridization of physiologic forms of Puccinia graminis tritici. MARGARET NEWTON, THORVALDUR JOHNSON, and A. N. BROWN.

Pustules of monosporidial origin were obtained by inoculating individual barberry plants with sporidia produced by telia of a number of single physiologic forms of *Puccinia graminis tritici*. The telia of each form had developed under controlled conditions.

The nectar on the pustules derived from the same physiologic form was intermixed ("selfing" individual forms), as was also the nectar on pustules derived from two different forms ("crossing" two forms). Only one form appeared strictly homozygous for pathogenicity; when selfed, this form alone was recovered. The other forms appeared heterozygous for pathogenicity; when selfed, each gave rise to one or more different forms, either previously known or hitherto unknown. From crosses between two forms, there arose forms differing from the parental ones, some previously known, others hitherto unknown.

From a reciprocal cross between two forms, a third form alone was recovered.

Barberry plants were inoculated with 8 forms *en masse*. Monosporidial pustules from each of the eight forms may be supposed to have developed. Some of these pustules coalesced and produced aecia. The nectar of the remaining ones was intermixed. From these inoculations were recovered several of the original forms and a number of other forms, some previously known, others hitherto unknown.

Hybridization and mutation in Puccinia graminis. E. C. STAKMAN, M. N. LEVINE, and R. U. COTTER.

Because of theoretical considerations and circumstantial evidence, it has seemed probable that different varieties and physiologic forms of *Puccinia graminis* might hybridize on barberries and that individual forms, even if selfed, might segregate if heterozygous. Craigie's discoveries furnished the necessary technique for experiments that have confirmed these probabilities. For example, from crosses between *P. graminis agrostis* and *P. graminis tritici* form 36, which apparently is relatively homozygous, several lines were obtained that are different pathogenically from both parents, and there is strong evidence that two of them never have been found in nature. Varieties and physiologic forms of *P. graminis* are dikaryotic clones which remain constant in the uredinial stage, except for mutation, but they may lose their identity in passing through the barberry because of segregation in the promycelia of the teliospores or because of the initiation of a new dikaryophase in the pycnia or aecia. The suspected rôle of barberry in the production of new forms is thus confirmed, and the facts emphasize the necessity of eradicating the bushes.

There is evidence, also, of mutation in parasitism. In a uredinial culture of *P. graminis tritici* form 1, constant pathogenically for 13 years, there suddenly appeared an apparent mutant, different pathogenically from anything the writers ever have observed. Extensive inoculations proved its constancy. It seems obvious, therefore, that new physiologic forms are arising both by hybridization and mutation. (Cooperative investigations between the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Minnesota Agricultural Experiment Station.)

A new mosaic disease of cucumber. R. H. PORTER.

In March, 1929, a sample of mosaic on cucumbers was secured from a greenhouse at Bettendorf, Iowa. Inoculation trials produced 100 per cent infection not only in the variety White Spine, but also in selfed lines of the variety Chinese Long. Differentiation of this mosaic from the common "white pickle mosaic" is based on symptoms, period of incubation, and host range.

The symptoms of the white pickle mosaic on cucumbers are marked stunting, drooping of the terminal leaves, faint to prominent mottling, and fruit infection. Its incubation period is three to six days. Infection occurs readily on cucumbers, canteloupes, and African stock citron, but not on watermelons and the variety Chinese Long cucumber. The symptoms of the "Bettendorf mosaic" on cucumbers are rigidity of the terminal leaves with yellow blotches at first distinct, later merging together. No visible symptoms appear on the fruit. Its incubation period is 6 to 15 days. This strain gave 100 per cent infection on all cucumbers, including the variety Chinese Long. Watermelon and stock citron also are readily infected but masking may occur.

The distribution of the Bettendorf mosaic is not definitely known but, apparently, it is much less common than the white pickle mosaic.

The resistance of cucumbers to mosaic. R. H. PORTER.

Individual, mass-selected plants, as well as selfed lines of the variety Chinese Long, are highly resistant to the "white pickle mosaic" disease. Three successive inoculations into the same plants at 12-day intervals failed to produce symptoms. Repeated efforts to transfer the disease from such plants to susceptible plants failed. Occasional plants of the variety Chinese Long, which are susceptible, may mask mosaic symptoms, but this seldom occurs throughout the life of the plant. Susceptibility to mosaic is dominant, but F_1 plants of Chinese Long × White Spine are not so severely stunted as the susceptible parent. Seeds from a back cross of the F_1 × White Spine produce plants which possess the short pickling type of fruit. Part of these are susceptible and part resistant but no genetic ratios have yet been determined. When 29 plants of this back cross were exposed to two different inoculations 9 remained resistant. Three attempts to transfer mosaic to susceptible plants from these 9 were unsuccessful.

Kale yellows (Fusarium conglutinans) in California. JAMES B. KENDRICK.

A tall, large-leaf variety of kale known as "Jersey" is grown extensively in the Petaluma district, Sonoma County, California, as a green food for chickens. About 80 per cent of approximately 4,000 chicken ranchers in the district use kale as a green food for their chickens. Kale yellows, which has symptoms similar to cabbage yellows, is widely distributed in the district and is forcing many ranchers to find a substitute crop for "poultry greens." The disease has not been observed by the writer elsewhere in California.

In 1927 numerous isolations from diseased kale plants yielded pure cultures of a Fusarium which subsequent inoculations showed to be the causal agent. Comparative cultural and cross-inoculation studies of it and *F. conglutinans* showed the two to be identical.

Pathogenicity of a number of collections of the cabbage-yellows organism. L. M. BLANK.

A study has been made of the pathogenicity of a number of collections of the cabbage-yellows organism, *Fusarium conglutinans*, upon cabbage and other subspecies of *Brassica oleracea*. Pure line isolations from 11 localities in 8 States were tested, under controlled conditions of soil temperature, upon pure lines of resistant and susceptible cabbage, and upon F_2 hybrids from resistant-susceptible crosses. The homozygous resistant lines remained entirely resistant to the attack of the various collections of the organism while the homozygous susceptible strains were uniformly infected. When tested against the F_2 hybrids isolations of the fungus reacted much alike in that the segregation of healthy and diseased plants was very close to the expected 3 to 1 ratio.

No evidence of selective pathogenicity was found when the collections were tested upon other subspecies, namely, Brussels-sprouts, cauliflower, kale, and kohlrabi. Upon these hosts, as upon commercial cabbage lines, slight variations in pathogenicity were observed but were not characteristic of any one collection of the organism.

While some variation was noted in their cultural characteristics, the pathogenicity range was similar for all the collections of the organism studied.

The nature of yellows resistance in cabbage. J. C. WALKER.

Further evidence is presented to confirm earlier reports that yellows resistance in cabbage is inherited as a Mendelian dominant. Physiologic responses of homozygous resistant lines of cabbage as compared with mass-selected resistant varieties and susceptible varieties have been studied. Homozygous resistant lines remain perfectly resistant

at a constant soil temperature as high as 24° C., while Wisconsin Hollander shows relatively little resistance in constant soil temperatures above 20° C. No clean-cut yellows symptoms appear in homozygous resistant lines, even at 28° C. or above. High air temperatures increase the rate of disease development in susceptible and mass-selected resistant strains, but fail to break down the resistance of homozygous resistant lines. Severe root pruning had no influence upon the expression of resistance in the latter.

Improved homozygous resistant lines have now been established for three midseason varieties, All Head Select, Marion Market, and Globe; and for two early-market varieties, Jersey Wakefield and Golden Acre or Early Copenhagen Market. The Jersey Wakefield strain will be introduced for general use in the fall of 1930 as Jersey Queen. The Golden Acre strain will be introduced as soon as sufficient seed is multiplied.

Indexing as a control measure for the yellow-dwarf disease of onions. W. J. HENDERSON.

The symptoms of yellow dwarf are stunting, crinkling, yellowing, and drooping of the leaves. The early appearance of the disease is due to planting infected bulbs. Later it spreads to adjoining healthy plants throughout the growing season. In most of the plants that become infected early the symptoms appear currently, but in others, infected late, no signs of yellow dwarf appears until the next growing season. Eighty lots of sets (60 in each lot) selected at random at harvest time were obtained from each grower at Pleasant Valley, Iowa, in the fall of 1928. These onions were grown in the greenhouse four weeks under favorable conditions for expression of the symptoms. The percentage of disease occurring in the different tests varies from 0 to 95. Samples of the same lots of bulbs were grown in the field in the spring of 1929 and the amount of yellow dwarf determined again. The amount of yellow dwarf that developed in the greenhouse and field trials compared favorably.

It is believed that this method of indexing the bulbs in the greenhouse furnishes a reliable method of determining, in advance of the normal growing season, the amount of infection in the set stocks.

Late blight tomato rot in California. G. B. RAMSEY and ALICE A. BAILEY.

Tomato-growing sections along the coast of California have suffered severely during the past few years from epiphytotics of late blight (*Phytophthora*). Total loss of fruit in some fields has been sustained. Cars of tomatoes shipped to markets have shown 50 to 100 per cent decay. Inspection certificates covering 30 cars shipped east in 1927 showed an average of 40 per cent infection. Lesions occur on vines as well as on fruit. Infection takes place at the stem scar, the lesions appearing in about four days as light brown water-soaked blotches. Transit experiments show an average radial increase of 1.5 cm. in lesions in four days. Rate of development decreases with increase in size of lesions. Lesions held two days following four days transit showed an average radial increase of .3 cm. during these two days. There is almost no spread in transit. Tomatoes harvested from blighted fields, but showing no signs of infection when packed, developed as high as 32 per cent infection in eight days, the average diameter of these lesions being 4.3 cm. Inoculations in the stem scar and through wounds elsewhere on fruits gave 55 to 77 per cent infection. Inoculations on uninjured surfaces failed to produce infection.

The inheritance of disease resistance in the onion. G. H. RIEMAN.

Colored-bulb onions (*Allium cepa*) which exhibited a high degree of resistance to the parasitism of the onion-smudge organism (*Colletotrichum circinans*) were crossed with susceptible colorless-bulb onions. Two germs responsible for resistance to smudge

have now been discovered (1) *W*, a gene for red color; (2) W_y, a gene for yellow pigment. Two different genes for the expression of white, and therefore susceptibility, have been found to be genetically distinct (1) *I*, a dominant inhibitor of red and yellow colors; (2) *w*, a gene for white. In the F_2 and F_3 generations of crosses between red and white varieties, white bulbs have appeared which were intermediate in tests for resistance to onion smudge. The interaction of the dominant inhibitor gene *I* and the gene for red *W*, effects the production of toxic chemical entities producing intermediate resistance.

Pathogenicity of Fusarium niveum and the resistance of some watermelon hybrids. D. R. PORTER.

Seventeen cultures of *Fusarium niveum* from watermelon from widely separated localities showed differences on artificial media in rate of growth, degree of sporulation, type of pigmentation, rate of starch digestion, morphology, and ability to change the pH. Seedling rot and seedling wilt are most severe at a soil temperature of 16°–18° C., and 25°–28° C., respectively. The rate of seedling wilt was positively correlated with the degree of soil infestation. In the field there is a tendency toward positive correlation in the rate of wilting and the air temperature.

Five edible hybrids, the variety Conqueror on four commercial varieties, Nos. 30, 33, 43, 90, and 137 have been isolated. In 1928 their resistance was, respectively, 22, 35, 46, 55, and 59 per cent, while check rows planted to the variety Kleckley Sweet showed only one per cent resistance.

Two edible hybrids, Q21 and Q23, in 1928, apparently chance crosses of unknown varieties on the variety Conqueror, were 68 and 64 per cent resistant, respectively, while the checks, six commercial varieties growing in adjoining rows, showed no resistance.

The most promising of the wilt-resistant strains resulted from the isolation of a resistant genotype from the susceptible variety Kleckley Sweet. The progeny of this genotype was approximately 50 per cent resistant in 1928.

The resistance of a watermelon genotype to Fusarium niveum. J. J. WILSON and DUKE V. LAYTON.

Inbreeding and natural segregation led to further isolation of lines having increased resistance to wilt in the progeny of K-S4, a genotype isolated in 1927 from the ordinary susceptible variety, Kleckley Sweet. The progeny of 22 inbred F_2 melons showed 8.7 to 73.3 per cent resistance in the tests in 1929. Two of the F_2 melons were 8.6 and 8.7 per cent resistant, two 16.0 and 16.6 per cent, one 26 per cent, six 31 to 38 per cent, seven 40 to 46 per cent, two 50 to 57 per cent, one 62 per cent and one 73 per cent resistant. One-half of the F_2 melons were over 40 per cent resistant.

Of the 1,759 initial plants representing the entire progeny of the F_2 melons 54 per cent were alive on July 11 and 35 per cent completed the full season's growth and bore a heavy crop of high-quality melons. Only 6 per cent of the 1,731 susceptible check plants from the variety Kleckley Sweet were alive on July 11.

Control of sweet-potato stem rot. DUKE V. LAYTON.

In 1928 and 1929 experiments were conducted to determine the value of some mercury seed disinfectants when used to control stem rot of sweet potatoes by seed and slip treatment. Three disinfectants were used on eight lots of diseased and healthy seed from three varieties. The percentage of healthy plants and acre yield in bushels for the seed treatments were, respectively, as follows: mercuric chloride 67.6 and 129.2, Semesan Bel 62.9 and 141.5, Corona PD7 58.1 and 130.3, compared with 52.7 and 104.8 for the un-

treated. Two organic-mercury dip dusts were used on six lots of slips grown from diseased and healthy seed from two varieties for the control of stem rot. For the two years, Corona PD7 showed both an increase in acre yield and percentage of healthy plants, while Semesan Bel increased the percentage of healthy plants both years but it decreased the acre yield in 1928. The percentage of healthy plants and acre yield in bushels for the slip treatments were, respectively, as follows: Corona PD7 83.8 and 166.6, Semesan Bel 81.1 and 149.6, compared with 61.7 and 142.6 for the untreated.

Soil reaction as influencing Phymatotrichum root rot. WALTER N. EZEKIEL and J. J. TAUBENHAUS.

Cotton was planted in rows 12 feet long, in boxes of seven different soils, and root rot was introduced by artificial inoculation at one end of each row. The disease spread farthest in soils of pH 7.6 and 7.7; spread shorter distances in soils of pH 6.3, 6.7, and 7.1; but attacked only one inoculated plant in acid soils, pH 5.5 and 5.8. Three other inoculation experiments yielded similar results, confirming previous field-survey results and showing that root rot is destructive in alkaline soils but unimportant in acid soils.

Attempts to develop control methods based on acidification of the soil have been continued. Excessive amounts of sulphur, added to soil in small containers, acidified the soil and reduced infection. Sulphur injury occurred here as in other experiments; however, there were series in which root rot was inhibited by acidities which did not affect the host. It is impractical to acidify highly calcareous soils, so this method of control would be of value only in limited regions, and care would be necessary to prevent injury from excess acidity. The method is in the experimental stage and is not to be recommended for general use on the basis of present limited knowledge.

Overwintering and spread of Phymatotrichum root rot. J. J. TAUBENHAUS and WALTER N. EZEKIEL.

Phymatotrichum omnivorum overwinters as active mycelium on living roots of infected plants, and as sclerotia and dormant strands. Roots of cotton and weed hosts survive after frost and may live until the following fall. Root rot continues spreading along roots of plants during winter. Living, infected roots transmitted the disease readily to normal plants, while dead roots did not. The fungus developed readily from living parts but not from dead parts of infected roots. Primary infections in fields have been traced to overwintered, infected roots of cotton and *Ipomoea trifida.* In certain fields from which clean fallow had eliminated roots, infection was from sclerotia, confirming Neal's observations.

Excavation of 117 isolated plants showed that spread from these primary infections to adjoining plants was along roots and not directly through the soil. In numerous inoculation experiments, soil from around infected plants consistently failed to produce infection; though high percentages of infection resulted from inoculations with live, infected roots. In the laboratory, the fungus extended through loose soil but more extensively along the walls of the containers. As yet, there is no direct evidence that similar spread, independently of roots, occurs in the field.

Cold resistance and susceptibility in corn. J. R. HOLBERT.

In some inbred and crossbred strains of corn there is high correlation between cold resistance in the spring and in the fall. In other strains, such correlation is not very significant, due to various influencing factors.

Cold resistance, in both spring and fall, has been found to increase as productive capacity of soil increases and vice versa. However, an inherently cold-sensitive strain

will not equal an inherently cold-resistant strain in functional capacity even when grown in a highly productive soil.

Cold resistance, in both spring and fall, was markedly lower in plants growing in soil high in moisture for a few days prior to exposure to low temperatures in field refrigeration chambers than in plants, comparable in other respects, growing in soil of moderate to low moisture content.

Plants injured by cold in the seedling or juvenile stages were later in flowering and in maturity, and possessed weaker root systems, than did control plants not injured by cold in the same stages. (Cooperative investigations between the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, Funk Bros. Seed Company, and Illinois Agricultural Experiment Station.)

Fungicidal use of organic-mercury compounds containing furan derivatives. J. J. WILSON and C. S. REDDY.

These compounds, when used as dust disinfectants of seed corn, effectively controlled the seedling blight diseases in three years of laboratory and field experiments. Four different toxic agents were prepared by varying the amount of furfuramide, mercuric chloride, mercuric nitrate, and ammonium hydroxide and sodium hydroxide in the cannizzaro reaction.

The fungicidal action of different amounts of these toxic agents in talc was tested in the laboratory by means of the visible-root sand-culture method, and in the field in thirty-hill plots replicated ten times. Nearly disease-free, artificially and naturally Diplodia-infected, naturally Basisporium-infected, and naturally Gibberella-infected seed was used. The fungicidal action was determined by lesion count and green plant weight in the laboratory and percentage of stand and yield in the field experiments. There was a high correlation between the laboratory and field results. It was found that these toxic agents, one of which is commercially known as Sterocide, exhibited equal fungicidal properties with the now available commercial compounds being supplied for seed-corn treatment. At low temperatures these new agents were especially effective in controlling seedling blight.

Development of corn ear rot from pure-culture inoculations. B. KOEHLER.

Inoculations were made with *Diplodia zeae*, *Basisporium gallarum*, *Gibberella saubinetii*, and *Fusarium moniliforme* on open-pollinated yellow dent corn at the parts indicated: (1) on silk without disturbing husks, (2) on tip of ear, husks opened to expose ear tip, (3) beneath outer husks toward butt end of ear, (4) in shank about two inches from ear, (5) in leaf axil subtending shank, and (6) in stalk about one inch below ear bearing node. Inoculations were made at 10-day intervals from August 1, time of silking, until September 30 when maturation was well advanced. Checks were treated with sterile water in the same manner.

All organisms caused infections through silk and tip of ear, August 10 being the period when most infections were obtained at these parts. Only Diplodia or Basisporium caused infection through the shank or down the husk. Diplodia alone was able to cause ear rot when inoculations were made in leaf axil, or in stalk.

Diplodia caused a high percentage of rot in all cases throughout the period used, susceptibility being greatest during August. The other organisms produced only slight to moderate increases as compared with the control and only during more restricted periods.

Control of barley stripe (Helminthosporium gramineum). C. S. REDDY and L. C. BURNETT.

Yield data in developing seed treatments were obtained by sowing treated and nontreated seed of 20 varieties of barley in 1928 and 18 varieties in 1929. The plots were planted once in 1928, but, in 1929, 3 dates of planting treated and nontreated seed at Ames and 2 dates at Mason City, Iowa, using 2 replications each time made 10 plots each of 18 varieties.

In addition to the data on seed treatment, the occurrence of barley stripe in the plots indicated the relative resistance of the varieties. This was particularly true because all the seed used in 1929 was harvested from the 1928 plots and, therefore, had somewhat similar chances for infection.

So far, these data show that the variety Minsturdi is the most susceptible and the variety Trebi, one of the most resistant. The nine varieties more susceptible to barley stripe were benefited by seed treatment with Ceresan and with a dust consisting of 6 parts sodium bicarbonate, 6 parts sodium bisulphite, 8 parts mercury chloride, and 80 parts talc. The nine more resistant ones were not benefited. There were indications that certain varieties are susceptible to injury from these seed treatments.

Susceptibility of durum wheats and emmer to Tilletia tritici. C. S. HOLTON.

That the recent increase in bunt in durum wheats, formerly considered resistant on the basis of field observations and experiments, is due to the presence of hitherto undescribed "physiologic forms" of *Tilletia tritici* is indicated by the results of artificial inoculations made at University Farm, St. Paul, Minnesota, and summarized below.

Variety	Source of inoculum and resulting percentage of smutted heads				
	Washington	California	Manitoba	North Dakota	Minnesota
Common					
Kota	42	54	43	43	15
Preston	7	12	16	2	1
Marquis	1	3	5	0.1	0.1
Marquillo	1	1	3	0.1	0
Hope	0	0	0	0	0
Durum					
Mindum	3	5	3	51	3
Pentad	12	8	9	42	10
Emmer					
Vernal	1	1	0	8	24

The first 3 collections are approximately equal in virulence on the varieties inoculated, but that from North Dakota is especially virulent on the durums, and that from Minnesota on Vernal emmer. These and the other differences apparent from the table indicate that there are at last 3 "physiologic forms" in the 5 collections.

Inheritance of resistance to Erysiphe graminis hordei, p. f. IV. S. M. DIETZ and H. C. MURPHY.

Susceptibility to physiologic form 4 of barley mildew is dominant and due to a single pair of factors. The inoculations of the barley hybrids were under controlled greenhouse

conditions. The classification into the resistant or susceptible classes was facilitated by a clean cut segregation of the F_2 and F_3. The response of 93 pure lines of barley was determined and the following hybrids made:

Chevalier C. I. 156 (susceptible) × Goldfoil C. I. 928 (resistant).
Goldfoil C. I. 928 (resistant) × Velvet (susceptible).
Odessa C. I. 927 (susceptible) × Goldfoil C. I. 928 (resistant).
Triebsol (susceptible) × Goldfoil C. I. 928 (resistant).

Twenty-two F_1 plants produced 790 F_2 plants, 588 of which were susceptible and 202 resistant—a deviation of 4.5 plants from the expectation. In the F_3 progeny tests, 49 susceptible F_2 plants produced 414 susceptible and no resistant plants. Fifty-two susceptible F_2 segregated into 436 susceptible and 152 resistant plants in the F_3. Twenty-five resistant F_2 plants were homozygous for resistance as they produced 261 resistant F_3 plants.

Inheritance of resistance to Puccinia coronata avenae, p. f. III. S. M. DIETZ and H. C. MURPHY.

The response of the F_1, F_2, and F_3 generations to a single physiologic form of crown rust was determined under controlled greenhouse conditions. Resistance in the following crosses was dominant and due to 2 pairs of factors, one of which was an inhibitor of resistance:

Sunrise 23– resistant (SSii) × Fulghum 41– susceptible (ssII).
Sunrise 23– resistant (SSii) × Fulghum 47– susceptible (ssii).
Guyra 51– susceptible (ssii) × Sunrise 23– resistant (SSii).
Golden 84– susceptible (ssii) × Red Rustproof 11– resistant (SSii).
Algerian × Calcutta 89– resistant (SSii) × Golden 84– susceptible (ssii).

The inhibitor for resistance was expressed only in the cross, Sunrise 23 × Fulghum 41. The F_1 was susceptible, the F_2 segregated in the ratio of 3 resistant to 13 susceptible, and the F_3 progeny tests indicated distribution of the F_2 in the ratio of 7 homozygous-susceptible, 6 segregating susceptible, 2 segregating-resistant, and 1 homozygous-resistant. In the remaining crosses the F_1 was resistant, the F_2 segregated in the ratio of 3 resistant to 1 susceptible, and the F_3-progeny tests indicated the F_2 ratio to be 1 homozygous-resistant, 2 heterozygous-resistant and 1 homozygous-susceptible. These results suggest the factorial analysis indicated above when S = resistant, s = susceptible, I = inhibitor for resistance. (Cooperative investigations between Iowa Agricultural Experiment Station and Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.)

Necrotic effect produced by wilting of susceptible varieties of wheat infected with leaf rust. K. D. DOAK.

Seedling wheat plants of Michigan Amber and Little Club susceptible to leaf rust (*Puccinia triticina* physiologic form 5) that were wilted temporarily for ½ to 2 hours at various periods after inoculation, showed immediate checking of the development of the rust. This checking was evidenced by total or partial necrosis only in the area occupied by the rust. Uredinia did not develop when plants were wilted before the time for their appearance. The tendency for partial necrosis was greater on plants wilted immediately before heading. Nonwilted plants of two susceptible varieties showed large uredinia and only slight chlorosis. Reinfection of leaves previously wilted and containing necrotic areas resulted in a development equal to that on reinfected nonwilted plants. Excess nitrogen did not alter the tendency for necrosis following wilting.

Temporary wilting was accomplished by removal and replacement of solution in sand cultures, drying and moistening of soil in pots, and by increasing transpiration rate with a

blast of dry air. All methods led to the same effect. Increase in temperature within the limit of tolerance of wilted and nonwilted plants did not modify the results.

Differentiation of symptoms and effect of leaf hopper feeding on histology of alfalfa leaves. A. A. GRANOVSKY.

Studies of alfalfa yellow top caused by *Empoasca fabae* Harris have differentiated these symptoms from other types of yellowing produced by such factors as the lack of soil moisture, high atmospheric temperature, bacterial wilt, mosaic, sudden excess soil moisture following a prolonged drought, and aphid injury. They each produce characteristic symptoms, markedly different from those caused by leaf hoppers. There is no striated discoloration of the areas between the lateral veins, which later involves the entire surface of the leaves, especially in the upper parts of the plants and in the new growth, so typical of leaf-hopper injury. There are also a shortening of internodes of the new growth, prolification, and rosetting of the new shoots in the axis of the leaves.

In leaf-hopper-injured tissue, microchemical tests revealed a greater accumulation of starch grains and sugars, especially glucose and fructose. The glucose grains were much larger than those in green tissue.

Histological studies show gradual disorganization and granulation of the plastids of affected tissue, clogging and isolation of vascular bundles by suberized or lignified layers, and complete disorganization of the phloem region of severely injured tissue. These phenomena are evidently due to enzymic secretions by leaf hoppers in a course of feeding.

Extracts of flax varieties toxic to fungi. E. S. REYNOLDS.

Unheated, sterile, water extracts made from several varieties of flax show different degrees of toxicity toward the growth of *Fusarium lini* Bolley in culture. There is some evidence of a correlation between the relative toxicity of these extracts and the degree of resistance of the flax varieties to the attack of this fungus. Stem, root, and leaf extracts likewise differ quantitatively in their toxic quality when equal quantities of dried material are used. Since the number of actively-functioning living cells in the structural parts indicated also differs similarly, the different quantitative results obtained by the present method of determining toxicity may be correlated with the amount of actively-functioning protoplasm.

Pythium root rot of strawberries in Louisiana. A. G. PLAKIDAS.

In making root-rot studies on strawberries in Louisiana, among many organisms isolated were several strains of Pythium. In a preliminary experiment, in the summer of 1928, inoculating the soil (sterilized and nonsterilized) at varying degrees of moisture content, in cans in the greenhouse, with a mixture of nine different strains of Pythium, and then bringing intact runner plants to root on the inoculated soil, root rot was produced. The effect of the pathogene on the plant is twofold: The primary roots may be vigorously attacked and become rotten, and the young plant killed in a few days; or, the attack may be slow, in which case the plant survives and continues to grow, but remains weak, chlorotic, and small in size as compared with the controls. When roots of the inoculated plants were plated, only one strain, instead of the nine used as inoculum, was reisolated. This strain has not been identified. It produces twisted, swollen hyphae (presporangia ?) in great abundance, but no spores of any kind on any of the media tried. The experiment was repeated and enlarged in the fall of 1928 with practically identical results. In this experiment, one set was inoculated with a mixture of the nine strains, as previously, and a second set with a pure culture of the single strain alone.

Root rot was produced in both cases, the disease being more severe where the single strain was used.

Fall applications of fungicides in relation to apple-scab control. G. W. KEITT.

The experiments previously reported have been continued and expanded, special attention being given to a group of arsenites (chiefly of calcium and copper) of varied composition, used individually and in various admixtures with other materials. Perithecia of *Venturia inaequalis* developed abundantly in nontreated leaves. Several of the more promising treatments reduced the number of perithecia which matured on sprayed leaves to less than one per cent of those on controls. The materials used in these treatments promise to be satisfactory with regard to effectiveness against the fungus, cheapness, and ease of application. However, the requirement of safety to the host has not been fully met. In many treatments the host injury has not been serious. In others it has been too severe for successful orchard use. The cases of severe injury from the more promising materials have usually been traceable to too early application. Amelioration of injury is being sought through delaying the treatments, dilution of materials, and modification of materials. Orchardists are cautioned against the use of these treatments until a safe and thoroughly tried method can be recommended.

Spray-oil injury in apple leaves and limbs. P. A. YOUNG.

Two to 16 per cent emulsions of petroleum oils cause chlorosis in Hibernal apple leaves. Emulsions with calcium caseinate (but not those with cresoap) produce angular mottling. Unsulphonatable parts of oils are mainly physical in their effects. A 16 per cent emulsion of a white oil was tolerated by leaves for two months, although they were visibly oily. Hypophyllous brown or purple sheens represent discolored veinlets. In severe cases, leaf margins curl upward. Toxic, aromatic, sulphonatable compounds in oils sometimes cause red or purple epiphyllous leaf spots. Large hypophyllous brown leaf spots are associated with premature defoliation. Oils enlarge wounds in leaves. Shading reduces oil injuries. Drouth increases injury from oil sprays. Early sprays may cause no symptoms until drouth occurs. Oily regions often remain green in leaves acquiring fall colors. White summer oils are fairly safe because the 0.75 to 2 per cent emulsions generally used rarely cause severe injuries. Winter oils (8 to 16 per cent emulsions) often kill buds, delay their development and cause leaf dwarfing. In sprayed apples, microtome sections stained with Oil Red O showed oil between spongy-parenchyma cells and in tracheae and vein parenchyma cells of leaves; also in tracheae, tracheoids, and pith and between phloem and collenchyma cells in stems.

Sulphur dust for the control of brown rot of peaches in storage. M. A. SMITH.

Experiments to determine the fungicidal value of Koppers dusting sulphur at different temperatures were carried on at Urbana, Illinois, during 1928 and 1929. Ripe Elberta peaches were carefully selected and divided into four lots. The first lot was brushed to remove the fuzz and was then given a uniform coating of dusting sulphur. The second lot was brushed and nondusted. The third lot was nonbrushed and nondusted. The fourth lot was nonbrushed but was given a uniform coating of dusting sulphur. After inoculation with fresh spores of *Sclerotinia fructicola*, the peaches were placed in controlled-temperature chambers ranging from 40° F. to 85° F. The amount of rot was noted at the end of 12 days.

The results showed that dusting sulphur was effective in controlling brown rot in the brushed and nonbrushed lots of peaches at the temperatures of 40, 45, and 55 degrees F.

At temperatures of 65° F. and above, no control of brown rot was obtained in any of the lots.

Brushed and nonbrushed peaches which were inoculated but to which no dusting sulphur was applied rotted readily at all the temperatures maintained.

These results show that definite fungicidal action was exerted by sulphur at a temperature as low as 40° F.

Control of yellow-leaf disease of cherries. DONALD E. BLISS.

Yellow-leaf disease (*Coccomyces hiemalis*) causes premature defoliation of cherry trees in Iowa nurseries. As a result, rapid growth and proper maturity of the wood are severely checked.

Thirteen fungicides were compared as to their effectiveness in controlling the disease on first-year budded English Morello trees. Twelve applications of fungicides were made between May 25 and August 14, 1929.

Results were based on measurements of height and caliper. One hundred and twenty-one trees sprayed with Bordeaux mixture, 4–4–50 with the addition of 1 pound of Kayso, averaged 34.01 inches tall and 7.43/16 inches caliper and exceeded similar averages of 105 untreated trees by 11.77 inches and 3.12/16 inches, respectively. Bordeaux mixture 4–4–50 produced differences of 6.125 inches height and 2.153/16 inches caliper. Koppers Thylox dust and Niagara Vitidust were as effective as Bordeaux alone. Bordeaux to which Kayso had been added was outstanding because of its ability to wet the youngest leaves and to deposit an unbroken layer of fungicide which was not easily removed by rain.

Unsatisfactory materials included: Lime-sulphur solution, 1–50 and Kayso; dusting sulphur; Koppers Ferrox and Nickel dusts; Thylox, Ferrox, and Nickel pastes (5 pounds to 50 gallons); Niagara Dry Mix and Soluble sulphurs (4 pounds to 50 gallons).

The occurrence of Gymnosporangium globosum on Pyrus malus in Iowa. DONALD E. BLISS.

Gymnosporangium globosum occurs commonly in Iowa on *Juniperus virginiana* and *Crataegus* spp. It has been found on trees of *J. virginiana* which also harbored the common cedar-apple rust, *Gymnosporangium juniperi-virginianae.*

On May 8 and 11, 1929, artificial inoculations were made on first-year budded apple trees in the nursery using galls of *G. globosum* with naturally expanded teleutosori. Sporidia which were discharged from the sori came to rest on moistened surfaces of the leaves. Distinct flecks appeared on leaves of the varieties Baldwin, Tolman Sweet, and Northwestern Greening after 13 to 19 days. Necrosis followed and no pycnidia or aecidia were formed. Noninoculated trees in the same rows showed no symptoms. Negative results were obtained from inoculation of Wealthy, Early Harvest, Ben Davis, and Benoni. Flecks of uncertain cause appeared on McIntosh, Red June, and Whitney.

Field observations on 50 varieties of apples in 1928 and on 150 varieties of apples and ornamental crabs in 1929 did not reveal aecidia of *G. globosum. Pyrus malus,* for the past two years, has not been found to serve as an alternate host of *G. globosum.*

Cane gall of black raspberry. W. M. BANFIELD.

Studies have been made of the nature and cause of the galls commonly found on black raspberry canes in Ohio, Michigan, Oregon and other States. The disease appears on fruiting canes in early summer as minute spherical galls or elongated ridges of white granular gall tissue. The galls may increase in size and number until they completely cover sections of the cane surface.

Bacteria isolated from such cane galls have differed consistently from a crown-gall-type strain, originally isolated from apple. Whereas the type strain induced large crown galls on tomato stems, the cane-gall organism induced only slight swellings. On red raspberry roots the type strain consistently induced large crown galls; the cane-gall organism, inconspicuous swellings. On black raspberry first-year canes the crown-gall-type strain induced comparatively small galls; the cane-gall bacteria, large galls similar to those from which they were isolated. From these galls, produced by inoculation, bacteria have been isolated which were typical of those inserted.

Preliminary bacteriological studies suggest that the cane-gall organism is quite different from the crown-gall-type strain. Further studies are now in progress to determine whether the cane-gall organism is a variety of *Phytomonas tumefaciens* or a separate species. (The University of Wisconsin and the Bureau of Plant Industry, United States Department of Agriculture, cooperating.)

Seasonal development of crown gall and hairy root. A. J. RIKER, E. HILDEBRAND, and G. W. KEITT.

Seasonal development studies of hairy root and crown gall of nursery apple trees were conducted during the major portion of the growing season of 1929 at Topeka, Kansas. Various meteorological records were kept throughout this period. Inoculations with pure cultures grown from single cells of the crown gall and hairy root organisms, respectively, were made at frequent intervals. The incubation periods were found to be longest in the spring or fall and shortest in the summer. The natural incidence of macroscopic hairy root was comparatively slight before the first of August, but increased rapidly thereafter and seemed to be correlated with the rapid increase in diameter of the trees. No naturally occurring crown gall was found on the trees examined. When correlated with the incubation periods following inoculations, these results suggest that under the conditions of this work the critical period for infection by the hairy root organism occurs not at the time the grafts are made but following the middle of June. However, the possibility of extended incubation periods deserves further attention. Infection was found to occur only through wounds, which ordinarily remained as open infection courts for only two days. Little if any infection was secured through uninjured callus. (The University of Wisconsin and the Bureau of Plant Industry, United States Department of Agriculture, cooperating.)

Histological studies of callus knots on apple grafts. JOHN E. SASS.

As a phase of a program of crown-gall investigations, histological studies were made of callus knots formed in the absence of a pathogen. In the apple grafts used (Wealthy on French seedlings), proliferation on the cut surfaces begins in the secondary phloem, not in the cambium. Subsequently, the secondary phloem, cambium, and primary cortex, but not the periderm, proliferate callus. The spongy cells of the respective callus masses formed by the stock and scion mingle, and together proliferate into the gap between the graft members. No elements of the woody cylinder centripetal to the cambium contribute to this process. The gap is rarely filled during the first year and no vascular bridging occurs through the filler callus. In poorly matched grafts, excessive callusing occurs and the establishing of cambial continuity between members is delayed. Subsequent cambial activity in a well-matched graft lays down a continuous and efficient cylinder of xylem and phloem. A sizable knot may form on the scion lip before the gap between members is one-third filled. The formation of this gall-like knot is conditioned, not by failure of vascular bridging through the filler callus, but by retarded establishment of cambial continuity between stock and scion.

The movement of the crown-gall organisms in the stems of tomato plants. SPAS IVANOFF and A. J. RIKER.

Studies have been made relative to the movement of *Phytomonas tumefaciens* in the stems of young tomato plants during the first four hours following inoculation. Pure-culture inoculations were supplemented by similar experiments in which each of the Gram-positive, non-motile bacteria (*P. insidiosum* and *P. michiganense*) and Burri's India ink, respectively, were mixed with crown-gall bacteria. These agents facilitated locating the less conspicuous crown-gall bacteria. Alone and in various combinations with the crown-gall organism, these agents were introduced into tomato stems through needle punctures. Dead cells of *P. tumefaciens* were also used. In histological sections prepared from this material, these agents, alone or mixed with the crown-gall bacteria, were found in three conditions; viz., as masses resembling zoogloeal strands, as clumps, and as individual bacteria or particles. After the first two minutes no significant progressive movement was observed in the 4-hour period studied. Dead crown-gall bacteria and India ink particles showed types of movement, rapidity of movement, and distributions within the tissue similar to those of living crown-gall bacteria. Various physical phenomena, such as negative pressure, capillarity, and convection currents, appear to deserve consideration in accounting for this movement.

Diseases of fruit trees in Illinois, 1922–1928. L. R. TEHON and G. L. STOUT (Presented by G. L. STOUT.)

The methods developed and used and a summmarization of the data acquired in a fruit tree-disease survey in Illinois covering the period 1922–1928 are reported upon. Distinction is made between prevalence of disease and intensity of attack. Scales for measuring the intensity of various diseases are described. From statistical indexes developed from the data, graphic presentations are made of the annual trends of diseases in their prevalence and intensity phases, and it is shown that years favorable to diseases of pomaceous fruits are generally unfavorable to diseases of drupaceous fruits. A final summary of data shows that fruit-tree diseases have had the average annual prevalence and intensities given in the following table:

Kind of tree	No. of diseases considered	Av. incidence of diseases per tree	Average intensity of disease attack		
			On fruit[a]	On twigs[b]	On leaves[c]
Apple	5	3.43	35.01	29.18	9.38
Peach	4	2.21	47.03	9.05	10.34
Plum	2	1.45	38.53	——	4.35
Cherry	2	1.34	15.79	——	4.30
Pear	1	.50	——	8.98	——

a, percentage of fruit infected; *b*, percentage of twigs infected; *c*, percentage of leaf area occupied by lesions. On both plum and cherry, the two leaf spots are counted one disease.

Probable identity of red and mild mosaic of black raspberries. W. H. RANKIN.

Three seasons' records of symptoms of virus diseases in a black-raspberry planting indicate that mild mosaic is an expression of red mosaic. In the Plum Farmer variety red mosaic is definitely shown in a large percentage of cases by the "black tips" of the sucker laterals. In many other individuals slightly darkened areas on the petiole of a

single leaf are the only symptoms. Between these two extremes various grades of suppression of symptoms are found. Mild mosaic on the fruiting lateral foliage was definitely correlated in 80 per cent of those showing red mosaic; only 5 per cent showing mild mosaic did not show red mosaic. The Plum Farmer population contained 2 per cent mild mosaic alone and 46 per cent red and mild combined, indicating that they are identical. Cumberland in a few cases showed symptoms of red mosaic approaching the black tip effect but more often a rosetting of the tips and occasional darkened areas on the petioles of a few leaves were the only symptoms. Mild mosaic on the fruiting laterals of Cumberland was present in 91 per cent of those showing red mosaic but 67 per cent of the plants showed mild mosaic only. That mild mosaic often represents the only symptom of red mosaic in Cumberland seems tenable.

A mosaic type in certain cases of peach yellows occurring near potatoes. GILBERT L. STOUT.

During a study of peach yellows, which, after a long period of supposed nonoccurrence in the State, has been found in Illinois since 1927, attention was attracted to a number of diseased trees with unusual foliage symptoms. The leaves of these trees were yellow-green to exceedingly pale or blanched with considerable greenness retained along the veins, which presented a marked color contrast with the rest of the leaf. The result was a striking mosaic-type appearance.

Yellows trees with this leaf coloration have had a previous history of proximity to potatoes and garden plantings.

It is suggested that more than one virus may cause peach yellows and that secondary symptoms may vary with the virus.

Slimy rot of head lettuce. J. G. BROWN.

Slimy rot of head lettuce is a field, transit, and storage disease which causes a large annual loss. It has been produced in healthy lettuce plants by inoculations, and the organisms have been reisolated. Recent studies disclose that certain conditions of the host favor infection.

Bacterial canker of tomatoes—present status of the disease. MARY K. BRYAN.

This disease has spread in recent years by means of the infected seed to the southern and western States, causing heavy losses to canners and market gardeners by reducing both quantity and quality of fruit. Often a large percentage of plants are killed before setting fruit. In other cases fruit spot has seriously reduced the amount of marketable fruit where vines had set a fair crop. Spotting of leaves and stems also occurs but appears to be of less economic importance.

Lesions are most conspicuous in the upper part of the plant; in the root a slight discoloration of the xylem is often the only noticeable symptom. As the systemic infection spreads through the cortex to the epidermis it breaks to the surface in open cankers on stems, midribs and small veins, setting free the bacteria which, under favorable weather conditions, produce secondary infections on fruits, leaves and stems.

Spotting of young fruits takes place through the numerous delicate surface hairs. Stomatal infections on leaves are at first minute, white, raised cankers; later are surrounded by a zone of dead gray tissue. If near together, large dead areas may be formed. Infection may reach the vascular system from these spots or from similar spots on stems.

Control of Bacterial canker of tomatoes. MARY K. BRYAN and O. C. BOYD.

Internal infection of tomato seed was demonstrated by planting externally disinfected seed, by cultures and by microtome sections showing bacteria in dense masses inside the seed coat just below the surface. Hence mercuric-chloride or semesan treatments give incomplete control.

Preliminary hot-water treatments of freshly cleaned and dry seed have shown that 54° C. for 1 hour retards germination slightly but does not reduce percentage of germination or sturdiness of plants. Both dry and freshly cleaned seed from infected fruit yielded *Aplanobacter michiganense* in cultures after external disinfection with mercuric chloride. Samples of the same lots of seed after treatment with hot water at 54° for 50 and 60 minutes gave no growth of the organism in cultures. Treatment for 30 and 40 minutes did not kill the organism in wet seed. As higher temperatures are injurious, this does not allow a sufficient margin for safety.

Field observations, so far, indicate that soil hold over may or may not be important. In New York there has been no recurrence of the disease for two years in fields where it was serious the previous year. It has been demonstrated, however, that the bacteria survive both summer and winter conditions in Georgia in compost from diseased plants and in fields where infected compost was used the previous year. A study of temperature and pH as influencing survival in the soil is under way.

Selection of seed from clean fields, rotation of seed beds and fields and disinfection of seed with mercuric chloride are recommended.

Further studies on the seed-corn maggot and potato black leg. J. G. LEACH.

A comparative study was made of the internal bacterial flora of the seed-corn maggot, the principal bacteria associated with black leg, and certain soil-inhabiting bacteria. It was found that certain soil saprophytes, such as *Pseudomonas fluorescens*, predominated, although pathogenic species were represented in each group. The insect should be considered as an occasional carrier of the pathogene.

Histological studies showed that bacteria of many kinds pass, apparently uninjured, through the intestinal tract of the larva. In the imago certain types of microorganisms apparently are destroyed, while certain rod-shaped species pass through uninjured. Nutritional studies indicate that bacteria, as such, are not necessary for the growth of the insect, but that they furnish available food by digesting the plant tissues. Certain germinating seedlings can be utilized in the absence of bacteria, while mature tissues can be utilized only after having been digested by microorganisms.

Survival of the potato-black-leg pathogene in the soil and some factors influencing infection. J. G. LEACH.

The black-leg pathogene survives the winter in the soil in Minnesota. The conclusion of earlier workers that this organism could not survive the winter in the soil appears not to be justified. Their conclusion was in part based on negative evidence, which, in the light of recent investigations on the methods of infection, has little or no bearing on the question. The pathogene is very resistant to low temperatures and is extremely resistant to desiccation when dried slowly in soil.

Excessive soil moisture, because it excludes oxygen, greatly inhibits the formation of wound cork by potato seed pieces. The black-leg pathogene, a facultative anaerobe, grows readily in soils too moist to permit cork formation. Under such conditions black leg can result from soil infection. Such inhibition of cork formation followed by soil infection is probably responsible for much of the development of black leg in moist soils or during very rainy seasons.

Some conditions determining potato-seed-piece decay and black leg induced by maggots. REINER BONDE.

In laboratory tests, adult flies of the seed corn maggot (*Hylemyia cilicrura*), caught in the open, did not infect potato seed pieces by direct contact. From eggs of such flies deposited in sterilized soil, maggots emerged which induced decay in potato slices in damp chambers. In seed pieces in soil, rapid decay was dependent upon shallow lesions caused by various fungi and bacteria on unhealed surfaces and upon the entrance of the maggots through such lesions. Thus, with maggots present, decay occurred in freshly cut seed pieces planted in nonsterilized soil (and attacked by fungi or bacteria), but not in suberized seed pieces planted in nonsterilized soil or in freshly cut seed pieces planted and becoming healed in sterilized soil.

In commercial potato-growing conditions in Maine, the maggots showed a similar relation to seed-piece decay, except that entrance lesions due to fungi and bacteria developed largely in storage and not in soil, even on freshly cut seed. From the inside of the puparia, *Bacillus phytophthorus* and some other potato-pathogenic bacteria have been isolated.

Similar effects were induced with seed-potato maggots (*H. trichodactyla*). Negative results were secured with the common house fly (*Musca domestica*), false crane flies (*Trichocera* sp.), a fungus gnat (*Sciara tribentata*) and various species of *Drosophila*.

The cabbage maggot as a disseminating agent of bacterial rots in the Cruciferae. REINER BONDE.

Turnips grown in the field could be grouped into three classes—(1) those with cabbage-maggot injury (*Hylemyia brassicae*) associated with a soft white rot; (2) those without maggot injury or rot; (3) those with maggot injury but without rot. The last group, however, developed the rot in storage, while turnips with no maggot injury remained healthy.

Maggots severely damaged Chinese cabbage and were found burrowing not only in the roots but up the fleshy midribs of the leaves. A rapid soft rot followed their trail. Some plants rotted before heads were formed.

Rutabagas were attacked by maggots but rapid decay was not observed in the field. However, from near the trails bacteria were isolated which were pathogenic on turnip roots, cabbage leaves, and potato slices. Such organisms could not be isolated from noninfested plants.

The wild mustard (*Brassica arvensis*) and the wild radish (*Raphanus raphanistrum*) were found generally injured at their roots by the cabbage maggot. Pathogenic bacteria often were obtained from the slightly discolored areas in the vicinity of the maggot trails but not from noninfested plants. Maggots from wild-radish roots were capable of inducing bacterial decay in slices of turnips and kohlrabi. These maggots, however, did not feed upon and infect potato slices.

Pupae of the cabbage maggot found in dry soil were surface sterilized and placed on agar plates until the flies emerged. From the inside of the puparia pathogenic bacterial cultures were secured. Similar cultures have been taken from inside mature flies caught in the field in early spring, which suggests that the pathogenic organisms overwinter inside of the pupae.

Several apparently different organisms were isolated from the hosts injured by maggots and from inside the insect pupae. These organisms have not been identified but appear from host range and symptoms to include *Bacillus carotovorus*, *B. phytophthorus* and *Bacterium campestre*.

A wilt of African daisy. B. B. MUNDKUR.

In the spring of 1929 African-daisy plants, *Dimorphotheca aurantiaca*, growing in the horticultural greenhouses of the Iowa State College, were found suffering from what appeared to be a wilt disease. Microscopic examination of the tap root and the stem showed that the xylem vessels had been invaded by fungal hyphae. Small pieces of the diseased tissue, surface sterilized and transferred to agar plates, yielded with marked purity and regularity cultures of a species of Verticillium. Seedling plants inoculated with pure cultures of the organism showed characteristic symptoms of the disease. In steam-sterilized soil infested with pure cultures of the Verticillium, plants also developed the disease. This Verticillium was compared with *V. albo-atrum* of potatoes in regard to its physiologic responses. It is similar to the potato Verticillium in respect to its growth on various media, its rate of growth, tolerance of acidity and alkalinity, and the formation of conidia.

Further progress with the control of aster wilt and yellows. L. R. JONES and REGINA S. RIKER.

Results in 1929 support those reported last year. With Fusarium wilt, selections for disease resistance again gave highly satisfactory results. Those considered stabilized in 1928 yielded like results in 1929. More recent selections approach stabilization. Promising resistant strains of all colors in type preferred by commercial florists have been secured. Trials made on "sick" soil in cooperation with John Bodger and Sons, seedsmen, Los Angeles, California, confirmed the resistance of eastern selections, and indicate the identity of the disease as it occurs in the East and the West. These trials also revealed promising new strains in commercial seeds surviving from earlier commercial culturing on sick soils. Tests are to be continued in the West where large-scale operations in the open are possible on sick soil in association with commercial seed culture.

In the prevention of yellows the use of inclosures covered with cloth of 22 x 22 threads per inch was again found effective but cloths somewhat coarser (12 x 12, 12 x 16, and 16 x 22) proved ineffective. A commercial florist found cloth-covered areas practical and profitable for cut-flower culture.

Transmission of aster yellows to the tomato. L. O. KUNKEL.

A number of unsuccessful attempts were made to transmit aster yellows to tomato plants by exposing them to yellows-carrying leaf hoppers of the species *Cicadula sexnotata*. During 1928 it was learned that a disease resembling aster yellows was prevalent on tomatoes in certain districts in Maryland. Since a number of solonaceous plants take aster yellows it was thought that the disease might be transmitted to tomatoes by grafting from closely related species. *Nicotiana rustica* was chosen for this purpose. Yellowed buds were transplanted to 12 healthy tomato plants of the Bonnie Best variety. All of the 5 plants in which the buds lived and grew developed the symptoms of aster yellows. The other 7 plants and 3 check plants remained healthy. Soon after the symptoms of yellows began to show, the *N. rustica* buds were cut out of 2 of the tomato plants. These plants did not recover but continued to show symptoms of yellows as long as they lived. It is, therefore, concluded that yellows was transmitted to the tomato. The fact that tomatoes are susceptible to this malady suggests that the disease prevalent in Maryland may be aster yellows.

Transmission of Sida mosaic by grafting. L. O. KUNKEL.

A mosaic disease common on *Sida rhombifolia* and other species of Sida in Florida and in Haiti is not transmitted by the ordinary mechanical methods. It is not carried

through the seed but is readily transmitted by budding or grafting. In symptoms and in behavior this disease closely resembles the mosaic of *Abutilon striatum* var. *thompsonii*.

Infectious chlorosis of the rose. RAY NELSON.

An infectious chlorosis of the rose has been present in the commercial rose houses of Michigan for at least four years. A recent survey of the larger houses has shown that the disease is increasing in importance, is generally present on certain varieties and that extensive losses have occurred in some instances. A loss of 9,000 plants of the Matchless variety was noted in one house. The disease usually causes a stunting of the plant, formation of midget or malformed leaflets, curling and leaf mottling of various degrees from faint mosaic speckling to extensive chlorotic areas along the veins. Flower buds on diseased plants are nearly always imperfect and salable flowers are seldom produced.

The disease has been found on a number of popular varieties of hybrid tea roses, has also been noted on Pernetianas and hybrid Pernetianas and is being widely disseminated through the shipment of diseased *Rosa Manetti* and Ragged Robin understocks. The percentage of disease observed in western plantings of these understocks has been from 10 to 100. The disease has been transmitted by budding and grafting on infected understocks but not by insects.

An infectious chlorosis of rose. R. P. WHITE.

A distinctive chlorosis of rose leaves accompanied by a general dwarfing of the entire plant, certain malformations and necroses of the leaf lamina and petioles, and frequently a root browning, was first observed in 1927 on greenhouse-grown roses. Since then it has been observed on 25 hybrid tea varieties of rose grown under glass from eight States and eastern Canada. In 1929 it was found occurring naturally on eastern outdoor-grown roses. The root browning was soon found not to be correlated with the chlorosis.

The disease has been observed occurring naturally only on hybrid tea varieties and *Rosa Manetti*. It has been experimentally transferred to *Rosa multiflora*, but attempts to transfer it to *Rosa odorata* and to *Pernetiana* and *Polyantha* types of roses have failed.

Transfer of the disease to healthy plants has been accomplished by the use of buds from diseased plants, disease symptoms appearing after one month on new growth of the originally healthy plant, in some cases far removed from the point of bud insertion. Insect-free dormant plants, when grown in insect-proof cages, have reproduced typical symptoms. Insect transfer has thus far failed.

Field control of rose diseases. R. P. WHITE.

Spraying experiments for the control of black spot of roses and certain canker diseases were conducted in two commercial nurseries on six varieties. Fourteen applications were made throughout the season, the first being made on May 15 and the final on September 24.

Excellent control of black spot was obtained with several proprietary sulphurs. Less satisfactory control was obtained with copper dusts and sprays or with concentrated lime-sulphur at the rate of 1 gallon to 50 gallons of water with 3 pounds of iron sulphate added to each 250 gallons of the spray. Control of the initial infections of brown canker and die-back due to the same disease was also obtained with many of the sulphurs but less satisfactory control was obtained with the coppers.

Data on growth responses to the various sprays used indicate that copper sprays produced a dwarfing of the plant out of proportion to the dwarfing produced by the failure to control black spot.

Two Phytophthora diseases of Rhododendron. R. P. WHITE.

Phytophthora cinnamomi has been determined as the cause of Rhododendron wilt. Most severe losses occur in *Rhododendron ponticum* and hybrid seedlings; *R. carolinianum* and *R. californicum* have been found susceptible.

The organism, a soil saprophyte, decays fibrous roots and advances up the stem in the phloem and cambium regions. Dark brown cankers are formed on the new growth where the pathogene also invades the cortex and pith and eventually the meristematic xylem elements. Infection may also take place at the soil level through growth cracks which occur during the second year's growth.

Studies on acidity and temperature-growth relations of the organism, and the effect of soil disinfectants indicate that the disease may be controlled by changing certain cultural practices and by the use of certain soil disinfectants.

Phytophthora cactorum has been found to cause a serious die-back of native and hybrid Rhododendrons of all ages. Infection has been secured by inoculations through the terminal bud and bud scales on the new growth, but not in tissue one year of age or older.

This organism has also been found to cause a leaf and twig blight of *Syringa vulgaris*, from which it is disseminated to Rhododendron. Cross inoculations have been successfully conducted.

Snow mold on turf grasses. ARNOLD S. DAHL.

Snow mold, caused by *Fusarium* spp., is common on lawns and golf courses in northern United States and Canada. The economic loss is greatest on putting greens where the disease produces grayish patches which may have a pinkish tinge. These patches are usually less than 12 inches in diameter but may run together to cover large areas. When the atmosphere is moist or snow is present and the temperature is near the freezing point, a mycelial weft covers the diseased patch. As the fungus grows under the snow, the disease is most conspicuous immediately after the snow melts. Heavy fertilization and covering the greens with straw late in the season encourage attacks of the fungus. Rye, wheat, barley, oats, fescue, creeping bent, and Kentucky blue grass have been infected in the greenhouse. A distinct difference in susceptibility has been found among the various strains of creeping bent used on putting greens. Corrosive sublimate and calomel have proven successful in controlling the disease.

Progress report on barley and wheat scab. JAMES G. DICKSON, R. G. SHANDS, P. E. HOPPE, HELEN JOHANN, and E. B. MAINS.

An epidemic of scab occurred again the past season, light in general severity, but extending westward over more area. Surveys showed severe damage in fields where wheat and barley were sown on poorly prepared corn land. Secondary spread and losses from the disease were increased materially by cutting scab-infected fields before thoroughly ripened. Control measures have developed along two lines, crop rotation and fall plowing especially for barley and the development of scab-resistant lines. (Cooperative investigations between the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, Wisconsin Agricultural Experiment Station, and Purdue University Agricultural Experiment Station.)

Some feeding tests with scabby barley. B. B. MUNDKUR and R. L. COCHRAN.

In the fall of 1928 many complaints were received by the Iowa Experiment Station regarding barley poisoning of hogs and poultry. This barley contained fungal hyphae in a large percentage of the grain. Perithecia were present on the surface of about 4 to 8 per cent. The fungus, on isolation, was identified as *Gibberella saubinetii.*

Hogs fed on an exclusive diet of this barley developed nausea for food and starved rather than eat it, while checks fed on clean barley were not sick and showed a slight increase in weight. After the fifth day the test animals on scabby barley began to vomit but did not develop any diarrhoea.

Mature chickens on the scabby barley showed no disease and lost no weight even when they were fed on artificially infected barley, while chickens, two weeks old, showed a loss in weight and developed a rough plumage. The birds were not on an exclusive barley diet and it was observed that they rejected a lot of the feed, picking out, as far as possible, the mash.

Guinea pigs rejected an exclusive barley diet. Fed on a half-and-half mixture of scabby barley and a mash, they lost in weight, but did not develop any disease symptoms such as was exhibited in the hogs.

Feeding scab-infected barley. B. H. ROCHE, G. BOHSTEDT, and JAMES G. DICKSON.

The farm utilization of scab-infected barley has been found economical by feeding it to cattle, sheep, and poultry. The ruminants and poultry make good gains on heavily scabbed grain with no apparent ill effect. Pigs, horses, and dogs as well as man are very sensitive to the accumulated products in the infected grains and will not tolerate low percentages of badly scabbed kernels. No method has been found to date whereby badly scabbed grain can be fed economically to pigs. Scabbed grain should be fed to cattle, sheep, or poultry on the farms rather than sold at a big discount at the elevator. (Cooperative investigations between the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and Wisconsin Agricultural Experiment Station.)

Report on the emetic substances in Gibberella-infected barley. ALLAN D. DICKSON, KARL P. LINK, B. H. ROCHE, and JAMES G. DICKSON.

The water extract from badly scabbed barley finely ground and extracted four to six hours was found to produce acute vomiting in pigs. The extract when freed from protein, polysaccharides and those nitrogenous substances precipitable with tannic acid is more active as an emetic for pigs than the original crude extract. The active substance or materials seemingly are associated with the fractions containing glucoside or basic nitrogen compounds. Further tests are being made with pigs and dogs in order to isolate and identify the substances. (Cooperative investigations between the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and Wisconsin Agricultural Experiment Station.)

Report upon scab-resistant cereal varieties. R. G. SHANDS, P. E. HOPPE, and E. B. MAINS.

Gibberella infection, scab, has played an important rôle during the past two seasons in further establishing such wheat varieties as Michigan Amber, Illinois No. 1, and Progress in the corn-winter-wheat area. There were marked differences in scab reaction in the wheat varieties tested the past few years with relatively less differences in the standard barley varieties. Testing and selecting for resistance have been difficult due to the complex relationship between the environment and the development of the diseases.

(Cooperative investigations between the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, Purdue University Agricultural Experiment Station, and Wisconsin Agricultural Experiment Station.)

The problem of seed transmission of the typical mosaic of tobacco. B. M. DUGGAR.

As a continuation of experiments with various substances that might be concerned in the adsorption of the virus of typical tobacco mosaic, experiments were made employing a variety of proteins and other complex substances. Although the results were varied, they were in certain instances positive; and this has led to a study of the influence of ground seeds of various types in inactivating the virus. The experiments have included seeds of diverse composition, that is, those primarily starchy and those primarily proteinaceous, representing several different families of plants.

Inactivation of the virus, which has been marked with certain proteinaceous seeds, is not a factor of the absolute protein content, but depends apparently on specific proteins or other specific material accompanying them. The ground tobacco seed is likewise capable of producing inactivation, but this is never complete at the concentrations employed. The probability of relation of transmission to adsorption and inactivation through storage proteins is pointed out.

Aphid transmission of plant viruses. ISMÉ A. HOGGAN.

The determination of the rôle played by various aphids in the transmission of specific plant viruses is of both fundamental and practical interest. That the virus of ordinary tobacco mosaic is transmitted by aphids has recently been laid open to question. Greenhouse trials have now demonstrated that *Myzus pseudosolani* and *Macrosiphum solanifolii* are capable of transmitting this virus from tomato to various solanaceous hosts, although these aphids are apparently incapable of transmitting the same virus from tobacco. On the other hand, they will readily transmit the cucumber-mosaic virus from both tobacco and tomato, as will also another species, determined as *Myzus circumflexus*. This latter aphid also appears unable to transmit the virus of ordinary tobacco mosaic from tobacco, in this respect resembling the peach aphid (*Myzus persicae*). No adequate explanation can yet be offered to account for this peculiar selective capacity of the aphids with respect to both the virus and the host plant.

It therefore appears that, although *Myzus pseudosolani* and *Macrosiphum solanifolii* may be factors in the dissemination of ordinary tobacco mosaic on tomato, none of the aphids studied is likely to be of importance in the dissemination of this disease in tobacco fields.

Cytological and bacteriological investigations of bean mosaic. RAY NELSON.

A cytological study has been made of two kinds of mosaic, mottle-type, common on pea bean, and rugose mosaic on Refugee. Free-hand, unstained section from petioles mostly have been used. These were supplemented by paraffin sections stained with iron haematoxylon and Giemsa stains. The presence of a minute organism has repeatedly been demonstrated in chloroplasts and in the cytoplasm of phloem, xylem, and parenchyma tissues of diseased plants. Invaded chloroplasts show first a small vacuolized area containing the organism. The chloroplasts are eventually destroyed and the organism is found in abundance in the plastid detritus. The organism may be localized or widely distributed in the plant. It is apparently a minute coccus usually occurring singly, in pairs, or in chains, but exhibiting considerable pleomorphism.

Using modified bacteriological methods, successful isolations have been made from very young seeds taken aseptically from immature pods and from leaf tissues from

mosaic plants grown under sterile conditions. The percentage of successful isolations apparently corresponds with the number of mosaic plants obtained from seed harvested from diseased plants. The organisms are sensitive to cultural conditions and frequent subculturing is necessary. Successful isolation and subcultures often fail without the aid of tissue cultures. Pathogenicity has not been proved. A morphologically similar organism has been isolated from highly susceptible varieties of beans showing no apparent symptoms of mosaic.

Spread of mosaic virus in tomato plants. W. A. MCCUBBIN and FLOYD F. SMITH.

A report previously presented indicated that the virus of tomato mosaic spreads through the stems at about the rate of 1–2 cm. per hour. Repetitions of this work have been carried out since that time and the results indicate that the passage of the virus is greatly delayed at temperatures somewhat lower than those presented earlier. The procedure involved rooting several branches of a tomato plant in surrounding pots so that any member of the resulting colony might be removed and grown independently, inoculation of one colony member with mosaic virus, removal of individual members thereafter at stated intervals, and subsequent observation of these to note the appearance or absence of mosaic.

When a section of the woody cylinder was removed from the stem connecting colony members the virus was apparently able to cross this point readily; and when a ring of cortex was removed at this point mosaic developed in the uninoculated shoot in several cases. It is believed that adequate precautions were taken to avoid accidental infection in these plants.

Investigations of tomato streak. S. P. DOOLITTLE and H. L. BLOOD.

Studies of tomato streak in Wisconsin show that three distinct forms of the disease exist. One of these is the familiar form produced by the combination of tomato mosaic and the juice of the potato. The other two forms, while of unknown origin, do not appear to contain the potato factor. The potato combination and one of the other forms produce a marked leaf necrosis and streaking of the stem, while the remaining form produces a severe stem streaking with occasional inconspicuous leaf necrosis.

In the expressed juice of plants affected with the potato combination the thermal death point of the virus is 65°–70° C. and its longevity *in vitro* is about 14 days. One of the other forms has a thermal death point above 80° C. and lives for at least 180 days. Similar studies with the remaining form have not been completed. Comparative inoculations using 45 species of the Solanaceae showed marked differences in the symptoms induced by each of the three forms.

Experiments with plants held at constant temperatures between 16° C. and 28° C. showed that the relative intensity of stem and leaf necrosis could be greatly altered or these symptoms entirely suppressesd by changes in temperature. The temperature reactions were distinctly different with each form of the disease.

(Cooperative investigations, Office of Horticultural Crops and Diseases, Bureau Plant of Industry, U. S. Department of Agriculture, and Wisconsin Agricultural Experiment Station.)

Mutilated seed—a contributing factor in defective stands of lima beans. W. A. WHITNEY.

In the summer of 1929 an alarming lack of stand of certain lots of California-grown lima beans was experienced by certain growers in the East. Examination of the seed revealed the presence of seed-coat and cotyledon cracking amounting to 50 to 80 per

cent. Seed lots on which no complaints were registered showed only 5 to 11 per cent similar cracking. The seed-corn maggot, diseases of fungous or bacterial origin, the use of commercial (food) stock, and old seed are factors which might add to the severity of the trouble, but no single one can be considered the cause of the lack of stand. Injury to the seed during threshing is held responsible for the mutilation and, as a result, for malformed seedlings and the generally poor stands from certain seed lots. Conditions of high temperature and low humidity in the seed-growing regions at the time of maturity and threshing result in extreme brittleness of seeds and makes them more susceptible to injury during threshing. It is suggested that more attention be paid to the speed of the threshing machine to eliminate the occurrence of a dangerously high percentage of mutilated seed.

Research on potato viruses in Montana. P. A. YOUNG.

Curly mosaic may be a genetic abnormality. Willowy tops represent one symptom of rugose mosaic. Rugose mosaic killed leaves and tops of inoculated plants. It was transmitted to potatoes separately having mild mosaic and leaf-rolling mosaic, thus indicating distinct viruses. Crinkle mosaic, leaf-rolling mosaic, mild mosaic, spindle tuber, leaf roll, and witches' broom were transmitted by core grafts. Fifty normal seed pieces, core-grafted with normal cores, produced normal plants. Mosaic in one selection of Idaho Rural potatoes apparently was not masked by temperatures of 25–30° C. Masking temperatures appear to differ for different forms of mosaic. Large, globular, intracellular bodies in rolled leaves are a symptom of leaf roll. Core grafts failed to transmit calico. Gray leaf spots in one form of calico were due to the absence of palisade cells. Tubers with witches' broom often have a normal dormancy period. Eye-bearing cores of potatoes with witches' broom grew after insertion into sugar-beet roots, producing peculiar symptoms in the beet leaves. Average reductions in yields caused by viruses: Triumph spindle tuber, 43.7 per cent; Triumph crinkle mosaic, 42.1 per cent; Gem spindle tuber, 64.3 per cent; Gem mild mosaic, 20.7 per cent; Idaho Rural crinkle mosaic, 20.4 per cent.

The viruses concerned in rugose mosaic of Irish Cobbler potatoes and the weed-host problem. W. D. VALLEAU.

Transfers from "healthy" Irish Cobbler potatoes to tobacco produce a mild disease, characterized by small necrotic rings on rubbed leaves and mild watered-silk patterns in new leaves (J. Johnson's mottle). When virulent, it produces necrotic ring-and-line patterns. (J. Johnson's ring spot—distinct from tobacco ring spot.) Transfers from rugose-mosaic Cobblers to tobacco produce "spot-necrosis" (of J. Johnson and ring spot of K. M. Smith) or predominantly vein-banding symptoms. Spot-necrosis may be separated into two distinct diseases; "healthy potato," and vein-banding (Smith's insect-transmitted disease), the latter commonly found in tobacco where potatoes have been grown. Vein-banding, from tobacco, and "healthy potato" mixed, produce spot-necrosis in tobacco and rugose mosaic in seedling potatoes; or if the healthy potato virus is virulent, a severe necrotic disease of potatoes. Vein-banding, etch, and severe etch cause mild, medium, and severe rugose symptoms, respectively, in otherwise virus-free seedling potatoes, from the tubers and second and third generation plants of which the viruses may be transferred to tobacco. Cucumber viruses also cause disease in potatoes. The viruses mentioned, and perhaps others, appear to spread from potatoes to some weeds and then to tobacco grown subsequently. As the weeds may harbor potato viruses they should be given more consideration in the potato-disease-control program.

Insect transmission of potato-virus diseases. R. W. GOSS.

For the past 4 years tests have been made of the ability of various species of insects to transmit different virus diseases of the potato. The work was conducted in the field with caged or partially caged plants of the Triumph variety. Owing to the frequent lack, or the masking, of current season symptoms, the results were obtained by indexing in the greenhouse and replanting in the field. Transmission of both spindle tuber and unmottled curly dwarf was obtained with grasshoppers, *Melanoplus* spp.; flea beetles, *Epitrix cucumeris* and *Systena elongata;* tarnished plant bugs, *Lygus pratensis;* and Colorado potato beetles, *Leptinotarsa decemlineata.* Spindle tuber was also transmitted by the leaf beetle, *Disonycha triangularis.* Less than 1 per cent of the uncaged control plants became infected with any of the virus diseases under study. A small number of tests using *Melanoplus* spp., *E. cucumeris* and *L. pratensis* with rugose mosaic, mild mosaic, and leaf roll were negative. All insects were fed on healthy plants before being used in the tests. By this means, it was found in a small number of instances, that *E. cucumeris, L. pratensis,* and *Melanoplus* spp. were carrying the virus of spindle tuber when collected.

Relation of Jimson weed to certain viruses of tomato and potato. R. W. SAMSON.

Two virus diseases of Jimson weed have been differentiated. The virus of the milder type closely resembles the virus (B of Fernow, mottle of Johnson) found in apparently healthy potatoes and can be obtained from this source. The virus of the more severe type produces more severe symptoms in tomato than that of the mild type, but resembles the latter in producing streak when inoculated into mosaic tomato plants. It has been transmitted to and recovered from 9 solanaceous species, including potato seedlings, without loss of virulence. It has not been found in uninoculated potatoes of standard varieties. It somewhat resembles the virus of Johnson's spot necrosis or rugose mosaic. Both of these Jimson-weed viruses have survived 80 days aging *in vitro* in tomato juice at 10° C. When the tomato-streak-virus complex is passed through Jimson weed the tomato-mosaic virus is not recovered. The latter produces only localized lesions in Jimson weed.

Effect of pressure in spraying potatoes with Bordeaux for control of leaf hoppers and aphis. C. F. TAYLOR and F. M. BLODGETT.

In connection with numerous spraying experiments using Bordeaux 5–5–50 in which different pressures were being compared throughout the season, quantitative records were taken of some of the diseases and insects present. The most interesting, from the standpoint of spread of virus diseases, were perhaps the opposite effects of the spray on the leaf hoppers and aphis. In respect to leaf hoppers, tip-burned leaflets per plant were counted on arbitrarily selected plants. There were most hopper-burned leaves on the unsprayed plats (average 163 per plant). At 200 pounds pressure there were 80 less and at 300 pounds 98 less than on the check. At 400 pounds pressure there was an average of 62 less than at 200 pounds. The aphis, however, varied consistently and significantly in the opposite direction. At 200 pounds pressure there were 41 more, at 300 pounds 62 more, and at 400 pounds 72 more than on the unsprayed, which averaged 20 per plant. Leaf roll plants found in one field averaged 81 more hopper-burned leaflets per plant than healthy plants. Similar differences in tip-burn between leaf roll and healthy plants appeared on sprayed and unsprayed, though the total was greater on the unsprayed.

A method of recording the distribution of copper dusts or sprays on leaves. F. M. BLODGETT and E. O. MADER.

During the past season a method of recording the distribution of copper on sprayed or dusted leaves, which may be used to supplement quantitative methods, was devised. Such a method was sought as an aid in testing the effect of different nozzles, spray-booms, pressures, and methods of dusting as they affect distribution of copper membranes on the plant. In brief the method is as follows: An iron-free paper is thoroughly wetted in a solution containing about 2 per cent potassium ferrocyanide and 5 per cent acetic acid. The paper is used while moist but without excess water. The selected sample of leaves, after wilting, is laid out on one sheet of this paper and covered with another. These are placed between pads of cotton in a strong press, such as an old-fashioned letter press. Medium pressure is applied. After about ten minutes the sheets are removed and washed in running water to remove excess chemicals. When dried these sheets form a permanent record. Areas of the leaves covered by copper are represented by brown areas on the paper, while iron, if present, will be represented by blue.

American and European leaf roll of potatoes. H. M. QUANJER and D. L. ELZE.

As phloem necrosis occurs in Dutch potato varieties suffering from leaf roll only in the veins and stalks, but in American varieties as a first-season tuber symptom (net necrosis Schultz, Folsom, Gilbert) the question of identity arises.

Apparently healthy tubers of Green Mountain, and healthy tubers of Dutch varieties, were planted alongside leaf-roll tubers of Dutch origin. Symptoms of primary leaf roll developed in the plants exposed to infection. In the Dutch varieties phloem necrosis was found only in veins and stalks, whereas in Green Mountain the new tubers also showed phloem necrosis. This was the first case of net necrosis observed by the writers.

American leaf roll has been transmitted by insects from diseased Green Mountain, Rural, and Irish Cobbler potatoes received from the U. S. A. to the Dutch varieties Duke of York, Paul Krüger (President), and Red Star in which phloem necrosis appeared only in the foliage, not in the tubers. This would seem to prove the identity of leaf roll in Europe and America.

Phloem necrosis in leaf-roll tubers of Dutch varieties can be demonstrated by allowing buds of the rose end to grow out into rootless shoots, and buds of the heel end to form roots. In the mother tuber, functioning as a stalk, secondary xylem and phloem develop, and in the primary-phloem strands necrosis can be observed.

"Pseudonetnecrosis" of the potato. H. M. QUANJER, T. H. THUNG, and D. L. ELZE.

In some strains of the variety Red Star an internal parenchyma necrosis is found as numerous brown spots inside and outside the xylem ring. It is transmitted by seed tubers to the progeny. It infects neighboring plants in the field. It has been transmitted by the aphid *Myzus persicae* from Red Star to Duke of York. No foliage symptoms are combined with it. Atanasoff, comparing it with some of the earlier figures of "netnecrosis," identified it with this American disease, and, finding it in potato plants infested with Aucuba mosaic also, considered it as a tuber symptom of this disease. Through the courtesy of Dr. Murphy the Suttons Early Regent variety was received with Aucuba mosaic, free from pseudonetnecrosis. It was later found by the present authors in several varieties which were free from Aucuba mosaic. It develops during storage, the more quickly the higher the temperature. Potato varieties differ in susceptibility—Paul Krüger (President) is very susceptible, showing the necrotic spots on the outside of the skin. A similar disease has been described by Fruwirth as "erbliche Eisenfleckigkeit" in Austrian seedling varieties. On account of its late development the transmission by seed tubers may escape attention.

Microscopic investigation of "pseudonetnecrosis" and "Kringerigheid" of the potato. L. C. P. KERLING.

The first-named disease is transmitted by seed tubers; the second occurs on certain soils only, enters during growth and manifests itself on the cut surface as concentric brown rings with the center at some point of the skin, often a lenticel, and is not transmitted by seed tubers. The rings are composed of necrotic cell groups, which resemble the necrotic cell groups found inside and outside the xylem in "pseudonetnecrosis."

In the necrotic cells the starch grains are fixed in a brown mass, consisting of a membrane, surrounding each individual grain and membranous deposits filling the spaces between the grains. These deposits are connected with the browned cell wall. After treatment with reagents they behave as suberised, lignified and pectic substances; the cell walls withstand the action of Jeffrey's fluid and Eau de Javelle better than the deposits; the deposits take the color of methylene blue, which leaves the cell walls unstained. Treatment with caustic potash decomposes the membranous deposits and shows them to be fatty products of the protoplasts.

The tissue surrounding the necrotic spots reacts as potato tissue always reacts in wounds; a wound phellem presses against the necrotic cells, it is surrounded by a wound phellogen, this in turn by a wound phelloderm. This reaction tissue is more fully developed in *Kringerigheid*, since this disease proceeds more rapidly.

Diseases of the streak type in potatoes. H. M. QUANJER and J. G. OORTWIJN BOTJES.

Core grafting has revealed the presence of different diseases of the streak type:

1. *Stipple streak* (Atanasoff). Spots and streaks in foliage and stalks; superficial necrosis in neighborhood of eyes and in eyes, causing "blindness." Showing as result of grafting with the carrier Zeeland Blue in Paul Krüger (President), Duke of York, Green Mountain and Noordeling; semilatent, resembling more or less crinkle (Murphy) and rugose mosaic (Schultz and Folsom), without tuber symptoms, in Bravo and Rose No. 4; resembling mild mosaic in Eigenheimer; latent in Zeeland Blue and two other old Dutch varieties. Red Star and a seedling of Red Star, on grafting with Zeeland Blue, behave as symptomless or nearly symptomless carriers.

2. *Stipple streak in May Queen.* Spots with strong indentations surrounding veins, scarcely any streaks, no tuber symptoms. Grafted on President it resembles streak, however without tuber symptoms.

3. *Stipple streak in Noordeling.* Milder, causing less leaf drop than stipple streak (Atanasoff). Grafted on Bravo a milder type of crinkle is produced than mentioned under 1.

4. *Stipple disease.* Spots more rounded, appearing later in the season, milder than 1, no tuber symptoms in Duke of York and Paul Krüger.

Top necrosis in the potato. J. G. OORTWIJN BOTJES and H. M. QUANJER.

Core grafting has revealed that some American and Scottish varieties and some strains of Dutch varieties are carriers of diseases causing strong necrosis chiefly in tops of plants, necrotic spots in pith and cortex, sometimes superficial necrosis of eyes, and always extended internal necrosis in tubers. Different diseases of this type exist.

1. *Yellow dwarf*, according to Barrus and Chupp, shows these symptoms in Green Mountain. In the cool climate of Holland the disease remains latent.

2. *Top necrosis latent in Green Mountain.* Grafting on Paul Krüger (President), Bravo, Red Star, Bevelander and Kerr's Pink produces top necrosis and necrosis of eyes and all other symptoms mentioned above; semilatent in Zeeland Blue, resembling mild mosaic; probably the same disease as found by Schultz (Science 62: 57).

3. *Top necrosis latent in Duke of York.* Grafting on Bravo, Red Star and Industry produces top necrosis; necrosis of eyes less evident; for the rest, complete foliage and tuber symptoms as described above; semilatent in Zeeland Blue, resembling mild mosaic.

4. *Top necrosis latent in Monoeraat and some strains of Red Star.* Grafting of Monoeraat on Zeeland Blue, Eigenheimer, or Duke of York via Eigenheimer reveals presence of top necrosis. No necrosis of eyes; for the rest, complete symptoms. Grafting with some strains of Red Star produces the same disease in Zeeland Blue, Paul Krüger, a seedling of Red Star, and Industrie. (Potatoes from abroad through courtesy of Dr. Murphy, Dr. Schultz and Dr. Fernow.)

Dry rot of corn caused by Diplodia frumenti and three morphologically related species. A. H. EDDINS.

Diplodia frumenti causes an ear and stalk rot of corn in Florida. The dark brown mycelium of this fungus penetrates the cob, kernels, husks, and stalks. Invaded kernels and husks of severely molded ears, as well as the pith of stalks, are blackened. Pycnidia are found on the stalks at nodes and internodes, in the interior of kernels, and embedded in stromatic masses of mycelium on the ears and husks.

Diplodia natalensis, D. tubericola, and *D. gossypina* also cause a dry rot of ears if they are artificially inoculated when in the dough stage. The symptoms of the ear rots caused by these species are similar to those caused by *D. frumenti.* The four organisms cannot be distinguished from each other in their imperfect stages, and they resemble each other in their nutritional reactions, temperature relationships, and growth on media of different hydrogen-ion concentration. They also produce the same type of rot in oranges, grapefruits, sweet potatoes, and watermelons.

Factors affecting the development of the aecial stage of Puccinia graminis. RALPH U. COTTER.

Under suitable conditions teliospores of *Puccinia graminis* may remain viable at least a year and a half. That they do not necessarily germinate during early spring rains before barberry leaves have unfolded is indicated by the fact that spores kept wet for 264 hours still were capable of causing infection. Temperatures of 12–21° C. were most favorable for the combined processes of infection and production of aecia. Infected barberries kept at 0° C. for three weeks developed pycnia when the temperature was raised to 18–20° C. Freezing killed infected barberries before it killed the rust. The minimum length of time necessary for infection by teliospores was 21 hours. On *Berberis vulgaris* infection may occur on the leaves, stems, spines, petioles, sepals, and berries. Leaves of *B. aetnensis* remained susceptible 16 days after they unfolded and those of *B. vulgaris* 12 days. Aeciospores still may be discharged 37 days after the aecia have formed and may cause infection 46 days after the appearance of the aecia. More than one physiologic form may be isolated from a single aecial cup. (Cooperative investigations between Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and Minnesota Agricultural Experiment Station.)

The presence of mycelium of Peronospora schleideni in the flowers of Allium cepa. H. T. COOK.

The frequent occurrence of onion mildew on onions grown on new muck soil in New York State, the uniform distribution of affected plants in the field at the time the first signs of disease appear, and the fact that the seed crop is often attacked indicate that the fungus may be carried in the seed. Evidence supporting this was obtained in the summer of 1928 when *Peronospora schleideni* was found fruiting on the seed stalk and

flower pedicels of an onion. Sections showed that the seed stalk was permeated with mycelium which could be traced through the pedicels into the various parts of the flower. It was definitely identified as the mycelium of *Peronospora schleideni* when it was found connected with the conidiophores on the pedicels. The mycelium was found in abundance in the petals, stamens, ovary, and ovules of the flowers. Its presence in the ovules indicates that it is also present in the mature seed.

A bacterium antibiotic to Ustilago zeae. R. H. BAMBERG.

The writer isolated from corn plants inoculated but not infected with *Ustilago zeae* in the field at St. Paul, Minnesota, a bacterium that prevents normal infection and also destroys colonies of the smut fungus growing on artificial media. When corn was inoculated with certain lines of *U. zeae*, approximately 70 per cent of the plants became normally infected, but infection was almost entirely prevented when the bacterium was added to the inoculum, incipient or abortive galls only being formed on a few plants. The bacterium also may destroy smut galls after they have been formed.

Colonies of *U. zeae* on artificial media were almost completely destroyed 10 to 14 days after inoculation with the bacterium, which apparently caused the disintegration of the sporidia. The bacterium also inhibits the development of colonies of *U. avenae*, *U. levis*, *Sorosporium reilianum*, and *Tilletia tritici*. The presence of the organism itself seems necessary to produce the deleterious effect, filtrates so far having proved innocuous. The writer tried many other bacteria but they had no effect.

The relationship of Bacterium medicaginis phaseolicola and Bacterium puerariae. FLORENCE HEDGES.

Cross inoculations with pure cultures of *Bacterium medicaginis phaseolicola* and *Bact. puerariae* have resulted in the production of typical kudzu halo spot and bean halo blight, confirming the suspicion of the writer that we are here dealing with one organism instead of two.

Successful cross inoculations have likewise been obtained by Boyd, who, however, did not use pure cultures but an inoculum obtained by soaking diseased leaves in water for 2 to 5 hours.

The name *Bact. medicaginis phaseolicola* (*Phytomonas medicaginis phaseolicola*) was published in PHYTOPATHOLOGY, December, 1926; that of *Bact. puerariae* in PHYTOPATHOLOGY, January, 1927; hence the latter becomes a *nomen nudum*.

Before the publication of the second paper on *Bact. puerariae* the writer had discovered bean halo blight in the west and, because of the striking similarity in the symptoms of the two diseases and the organisms associated therewith, she suspected a common cause. At this juncture she was by no means sure that the western bean disease was identical with the one described by Burkholder in New York as due to *Bact. medicaginis phaseolicola*, since his description gave a considerably different picture from that exhibited by the western fields. Hence the name *Bact. puerariae* was allowed to stand pending further investigations.

In the meantime, recent experimental work and more extensive field surveys, including observations on Burkholder's bean plots at the Cornell Experiment Station, have left no doubt that the halo blight of bean in the west, middle west, and south and kudzu halo spot are identical with the New York disease of bean due to *Bact. medicaginis phaseolicola* Burkholder.

An albino strain of Aplanobacter michiganense. MARY K. BRYAN.

A pure-white strain of *Aplanobacter michiganense* has been separated from three different isolations at various times. The loss of color is permanent on culture media. Inoculations on tomatoes with this strain have produced typically diseased plants from which the white organism has been reisolated. This strain, which is Gram-positive and non-motile, agrees with *A. michiganense* in all of the cultural tests made.

Effect of ultra-violet radiation upon sporulation in Macrosporium and Fusarium. G. B. RAMSEY and ALICE A. BAILEY.

Definite stimulation of spore production occurs in cultures of *Macrosporium tomato,* and of *Fusarium cepae* on exposure to ultra-violet radiation produced by a quartz-mercury arc. Increased sporulation appears to be a result of stimulation rather than an indirect result of inhibitory action. Greatest sporulation occurs when filters are used the lower limits of transmission of which are between 2535 and 2800 Angstrom units. Lethal effects appear with shorter wave-lengths. Slight stimulation results when filters transmitting no lower than 3120 A. U. are used, but none with those transmitting only to 3334 A. U. Great increase of sporulation occurs with irradiations of 15 to 30 minutes. Stimulation of spore production is not due to changes of temperature nor to change of the culture medium as a result of irradiation. Long exposure to intense direct sunlight through filters transmitting no lower than 3120 A. U. induces abundant sporulation. However, the experiments with the mercury arc tend to show that the difference in amount of sporulation under Vitaglass (transmitting to 2650 A. U.) and under filters transmitting as low as 3020 to 3120 A. U. is not due solely to a difference in intensity in this region but to a difference in the total energy transmitted.

Standardization technique in certain virus studies. B. M. DUGGAR.

Crude juice from mosaic-diseased or healthy tobacco leaves pressed out or filtered through cotton or filter-paper contains a variety of particles which interfere with many operations. Adsorption studies with the virus of typical tobacco mosaic have suggested proximate methods of purification by removal of these grosser particles. A diatomaceous trade preparation called supercelite has proved exceptionally valuable in purification technique; and, in connection with fractional dilution, the use of this substance has become a standard procedure.

Thermal inactivation tests, rendered increasingly more necessary owing to the use of temperature as a criterion in distinguishing certain forms of mosaics, have been standardized by the use of a more adequate direct immersion method and glass capillaries.

Stomatal infection with the virus of typical tobacco mosaic. BURT JOHNSON and B. M. DUGGAR.

Extensive series of experiments have been made with the view of determining the conditions limiting stomatal infection in tobacco mosaic. The experiments were conducted both in the greenhouse and in an insect-proof tent in the field. In order to secure data on any possible correlations between the diurnal movements of the stomata of the host and the production of disease, applications of the virus were made by means of an atomizer, lots of 10 plants being sprayed hourly throughout the day in two series. Records of general weather conditions, temperature, and humidity were taken. At the time of each spraying strips from both the upper and the lower epidermis were removed and placed in absolute alcohol. Subsequent study of the stomatal conditions indicated that all stomata are never completely closed, and that the stomatal diurnal movements are not

correlated with the environmental conditions within the limits employed. Moreover, the percentage of disease production is not correlated with these environmental changes nor in any way related to the time of day at which sprayings were made. An outstanding feature of these results is the high rate of infection through the stomata as entrance channels, presumably. The incidence of disease averages about 80 per cent.

The effect of some mosaic diseases on the cell structure and the chloroplasts. MELVILLE T. COOK.

Studies on the sugar cane and tobacco mosaics have been continued, together with the mosaic diseases of tomatoes, cowpeas, *Abutilon hirtum*, and canna. Tissues from chlorotic and green areas of diseased leaves were compared with tissues from normal leaves of approximately the same age. These studies confirm the statements made by many writers that the chlorotic areas are thinner than the green areas or than normal green leaves of the same age, the palisade is undeveloped, the mesophyll is reduced, and the cells compact. These modifications vary with the severity of the attack and the development of the tissues at time of attack. It is due to inhibition.

The chloroplasts in the chlorotic areas are reduced in size and number in the very young leaves but increase in size and number with age and exposure to sunlight until the patterns almost or completely disappear. This can be traced in sections made from a series of leaves beginning with the very youngest in which it is possible to detect the pattern. This appears to be due to inhibition and not to disintegration as stated by many writers. In the case of the *Abutilon hirtum* there is little or no tendency for the chloroplasts to become normal and the chlorotic areas do not become green.

Physiologic forms of barley mildew, Erysiphe graminis hordei. E. B. MAINS and S. M. DIETZ.

It has been shown by Marchal, Reed, and Salmon that the powdery mildew of barley is restricted to a few closely related species of Hordeum such as *H. vulgare, H. intermedium, H. distichon,* and *H. difeciens.* These studies have resulted in discovering a number of very resistant varieties in these species of Hordeum. Using such varieties, five physiologic forms of the mildew have been differentiated. Thus Nepal C. I. 595 is resistant (type 1–2) to physiologic form 1 and susceptible to the other four physiologic forms. Peruvian C. I. 935 is resistant (0–1) to physiologic forms 1, 2, and 4 and susceptible (4) to physiologic forms 3 and 5. Black Hulless C. I. 666 is resistant (1–2) to physiologic forms 1 and 2 and susceptible (3–4) to physiologic forms 3, 4 and 5. Goldfoil C. I. 928 is highly resistant (0) to physiologic forms 1, 2, 3, and 4 and susceptible (4) to physiologic form 5. A number of varieties were found to be resistant to all five of the physiologic forms.

Physiologic specialization in Sphacelotheca sorghi. L. E. MELCHERS, C. H. FICKE, and C. O. JOHNSTON.

Three years' data on varietal reaction of sorghums to covered kernel smut prove the occurrence of at least 3 physiologic forms of that organism. Eighty varieties, selections, and hybrids representing the principal groups of sorghum have been used.

Varieties of kafir, sorgo, broomcorn, and kaoliang, as well as miscellaneous sorghums, are attacked by all 3 physiologic forms. Form 1 does not attack milo, hegari, and feterita. Form 2 attacks milo and hegari, but not feterita. Form 3 attacks feterita and certain feterita hybrids, but not milo. Certain Red Amber X feterita hybrids and Spur feterita have not yet been attacked by any of the three forms.

Twenty-three varieties show definite differential reaction and have been arranged in seven groups; viz., one group attacked by all 3 forms; one group attacked by only form 2; one group resistant to all 3 forms; one group susceptible to forms 1 and 3 and resistant to form 2; one group resistant to forms 1 and 2 and susceptible to form 3; one group susceptible to forms 1 and 2 and resistant to form 3; and one group resistant to form 1 and susceptible to forms 2 and 3. These groups have been arranged in a dichotomous key for the identification of physiologic forms of covered kernel smut. (Cooperative investigations by the Kansas Agricultural Experiment Station and the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.)

Stem rust infection of Khapli emmer and Hope wheat in Peru. E. V. ABBOTT.

The results of field experiments with Khapli emmer and Hope wheat during 1928 and 1929 have shown that these varieties are susceptible to *Puccinia graminis tritici* in Peru. When grown in an isolated field Khapli matured with only a trace of stem rust, but when exposed to heavy inoculation by planting near more susceptible common wheats 100 per cent of the plants in one-tenth-acre plots rusted. Although the individual rust pustules were relatively small, they were often so numerous on the culms as to coalesce and cause complete girdling.

Hope rusted more heavily than Khapli, numerous pustules appearing on the culms, necks, leaf bases, glumes and awns. Many culms broke when the kernels were still in the milk stage, and the kernels from heads that matured were badly shrivelled.

Although weather conditions during the growing season were very favorable for rust infection, it is not believed that such high virulence can be attributed to this factor alone. In the laboratory the twelve differential hosts of Stakman and Levine have proved susceptible when artificially inoculated. It is concluded that a new and virulent form of *Puccinia graminis tritici* exists in Peru.

Physiologic specialization in Puccinia coronata avenae. H. C. MURPHY.

Single-urediniospore isolations were made from 45 collections of crown rust, *Puccinia coronata avenae* of which 32 were collected on Avena and 13 on Rhamnus. These cultures were each grown on pure-line selections of 33 varieties and species of oats. Eight of these, acting as differential hosts, disclosed the following 9 physiological forms:

Belar—resistant
- Red Rustproof C. I. 1079—resistant
  - College Algerian C. I. 2052—resistant ..... form III
  - College Algerian C. I. 2052—susceptible ..... form VIII
- Red Rustproof C. I. 1079—susceptible
  - Cowra—resistant, form IX; Cowra susceptible ..... form VII

Belar—susceptible
- Iowa No. 69—resistant; *Avena strigosa*—resistant
  - Anthony C. I. 2143—resistant form IV; Anthony C. I. 2143—susceptible ..... form II
  - *Avena strigosa*—susceptible ..... form I
- Iowa No. 69—susceptible
  - Iowa No. 102—resistant, form VI; Iowa No. 102—susceptible .. form V

The 13 aecial collections on 5 different species of Rhamnus represented the following physiologic forms: All 4 collections from *Rhamnus cathartica*, form III; all 6 from *R. lanceolata*, form V; one each from *R. tinctoria*, *R. montana*, and *R. infectoria* were

forms VII, VIII, and IX, respectively. Forms III and V from Rhamnus and I, III, and V from Avena occurred most frequently. Form V was the most widespread and virulent, none of the varieties, pure-line selections, or species being resistant to it. Form I predominated in the Southwestern States. (Cooperative investigations between Iowa Agricultural Experiment Station and Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.)

Dissociations and associations in some strains of Fusarium moniliforme. LEON H. LEONIAN.

Numerous strains of *F. moniliforme* were isolated from corn plants showing symptoms of root rot. Inoculation experiments indicated that these strains possess varying degrees of pathogenicity. After making a single-spore culture from the most virulent of these strains, an attempt was made to dissociate it into as many variants as possible in order more fully to study its scope of fluctuability. As a result of this, some fifty variants were separated from this one strain. After discarding the less-distinct types, there still remained 25 variants easily distinguishable from one another by macroscopic appearance and often by their degree of pathogenicity. The stability of the types was found to be only relative and highly variable, as a given variant would split into new types or revert to the original without any system or regularity. When artificially mixed in petri-dish cultures, usually a perfect blend followed, and colonies resulting from these artificial reassociation duplicated the natural dissociation types observed in plate cultures. When a purple form of these variants was mixed with an orange form, the latter representing a different isolation and undoubtedly a separate strain, often a perfect blend resulted and it required selection for several generations before the types segregated in pure form. In one instance the blending was so perfect as to produce intermediate and new types not observed before. So far these new types have retained their characteristics despite selection continued for generations.

A physiologic form of Ustilago striaeformis parasitizing orchard grass. W. H. DAVIS.

Ustilago striaeformis which causes leaf smut of timothy has been reported as parasitizing both orchard grass and timothy. However, it is not known whether the smut organism which parasitizes these two hosts is one physiologic form, as commonly believed, or a composite species of two physiologic forms.

This investigation was undertaken to solve:

1. Will chlamydospores removed from orchard grass, after-ripened and germinated, infect seedlings of timothy (*Phleum pratense*)?

2. Will chlamydospores removed from timothy, after-ripened and germinated, infect orchard grass?

It is to be noted that reciprocal inoculations with chlamydospores of *U. striaeformis* from the two grass hosts failed to show infections, while inoculations within the host species produced the disease and that the smut organism parasitizing orchard grass is a physiologic form differing from that parasitizing timothy.

Physiologic specialization in Phlyctaena linicola. H. A. RODENHISER.

Phlyctaena linicola comprises several physiologic forms. Four forms have been isolated from flax grown in different localities in Minnesota and many more have been isolated from sectors that appeared in colonies on artificial media. Colonies of monosporidial lines can be distinguished by color, topography, surface, consistency, type of margin, the degree to which they produce conidia and by differences in the amount of growth at different temperatures.

Five varieties of flax were inoculated in the greenhouse with 4 culturally distinct monosporidial lines but there were no observable differences in pathogenicity. In the field, however, there were differences in the degree of infection caused by a monosporidial line which produces conidia abundantly, and by another which arose as a sector in a growth therefrom. The range of susceptibility to pasmo in a large number of flax varieties and selections was very wide. (Cooperative investigations between Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and Minnesota Agricultural Experiment Station.)

Physiologic specialization in Puccinia triticina in Holland. S. J. WELLENSIEK.

Among collections of the orange leaf rust of wheat from 5 different localities in Holland, physiologic forms 11, 14, and 15 were evidently found to be present. Form 11, therefore, seems to be widespread, both in U. S. A. and in Europe, while the other forms of Mains and Jackson seem to be restricted to U. S. A. and Scheibe's forms to occur widely distributed in Europe.

The wheat varieties usually grown in Holland were all found to be moderately to highly susceptible to all 3 physiologic forms occurring in Holland. Some of the foreign varieties, however, gave a negative reaction with these 3 forms. Breeding for rust resistance, therefore, must be done by crossing foreign varieties with the Dutch ones.